Station Circular No. 64 (Third Revision)

NEW INSECTICIDES: THEIR USE, LIMITATIONS AND HAZARD TO HUMAN HEALTH

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PCJ 5/16/50

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R. L. Webster*

New insecticides bring new problems. Not only must the new chemical be effective in combating insect pests, but it must also be reasonably safe for the spray operators to use, leave no residue on fruit and vegetables that is injurious to human health, cause no blemishes on the crop, break down rapidly enough so that no residue builds up in the soil, cause no off-flavor to the crop at harvest, and finally, be compatible with other agricultural chemicals.

Toxicity of insecticides to mankind is determined for the most part by analogy. Laboratory animals such as white rats, for instance, are fed on a diet of some foodstuff to which the insecticide has been added, to determine any chronic effects--those which appear only after a period of weeks. Such effects may exhibit themselves as damage to the liver, gall bladder, kidneys, or other vital organs.

Toxicity is also measured in terms of a mean lethal dose, i.e., that quantity required to kill 50 per cent of the animals under experimentation when fed by way of the mouth. This is expressed in terms of mg/kilo; milligrams of the toxic agent per kilograms of body weight of the animals concerned.

Comparisons that certain of the new insecticides are more toxic or less so than DDT are based usually on the acute oral toxicity. For example, if the acute oral toxicity of DDT is the same for man as it is for rats (which may or may not be true), it would require $6\frac{1}{2}$ ounces of DDT to kill a man weighing approximately 150 pounds. The acute oral toxicity of DDT to white rats is 250 mg. per kilo. Assuming a ratio using DDT as a base level of 1, nicotine is rated as 25 times as toxic as DDT, parathion 70 times as toxic, and TEPP 125 times as toxic.

On the other hand, Rhothane (DDD or TDE) is said to be 1/10 as toxic to warm bloods as DDT, while methoxychlor, another close relative, is rated as 1/24 as toxic as DDT. While our investigations in the Pacific Northwest generally show that Rhothane and methoxychlor are less toxic to some insects, the difference is not as great as the figures quoted might indicate. In fact, with individual species of insects, Rhothane may be fully as effective as DDT at the same concentration.

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Tolerances. While the federal Food and Drug Administration has ample authority to seize any fruits or vegetables where toxic residues are detected, it is realized that insecticides are necessary to protect those crops. In order to protect the public health on the one hand and the fruit grower on the other, the following informal tolerances have been established on apples and pears over a period of years:

Arsenic	0.025	grain per pound
Lead	0.05	grain per pound
Fluorine	0.05	grain per pound
DDT	0.05	grain per pound

The tolerance on fluorine was first set at 0.02 grain per pound in 1938 on fruit shipped within the jurisdiction of the federal Food and Drug Act. Later this was changed to 0.05 grain per pound. More recently this tolerance was declared invalid in a federal court in California on the ground that fluorine was a gas and thus there could be no residue involved. This court decision renders tolerances on lead and arsenic untenable, because neither arsenic or lead is present on fruit as such, but comes in combination as lead arsenate. Consequently, such tolerances are regarded as informal tolerances. Legal tolerances may be established only through the mechanism of public hearings, according to the U. S. Food and Drug Administration.

Before setting legal tolerances, evidence must be presented (1) on the necessity for using added substances for controlling the enemies which interfere with the production of fresh fruits and vegetables, (2) as to whether the substances required for the production of fresh fruits and vegetables are poisonous or deleterious, and (3) on the amounts of these substances which are poisonous or deleterious which are received from all sources by consumers.

DDT: First synthesized in 1874 by a German chemist named Zeidler, DDT was patented as an insecticide in 1939 by Geigy, Inc., a Swiss concern. DDT is an abbreviation of the chemical term dichloro-diphenyl-trichlorethane. There are many trade names.

In recognition of the importance of DDT in the field of preventive medicine, Dr. Paul H. Mueller was formally awarded the Nobel prize in physiology and medicine in ceremonies held in Stockholm, Sweden, December 10, 1948. Dr. Mueller has been associated with the J. R. Geigy firm at Basle, Switzerland, since 1925. DDT had unprecedented development as a synthetic insecticide because of its unusual properties of wide range of insecticidal action, simple structure promoting ready synthesis, stability to light and air resulting in enduring residual toxicity and low mammalian toxicity, according to Robert L. Metcalf.

Technical DDT is a white to cream colored amorphous waxy powder produced by the reaction of chloral with mono-chlorobenzene in the presence of concentrated sulfuric acid. While the technical material has a variable

composition, it is composed, for the most part, of two isomers. Of these the para-para isomer is far more toxic to insects than the ortho-para isomer. Commercial DDT may contain from 65 per cent to 85 per cent of the para-para isomer; 15 per cent to 21 per cent of the ortho-para isomer.

Where DDT is an effective control for specific insects, the para-para content of the commercial product has generally been sufficient, except where resistance has been developed after several years' use, as in the case of house flies and mosquitoes. The melting point of the para-para isomer is given as 108-109° C., that of the ortho-para isomer, 73-74° C. That of the technical product is usually given as 89°.

During the war years, DDT was used on a large scale for mosquito control in army camps, to combat flies and bedbugs, and to impregnate clothing for body lice. Early reports from Switzerland indicated the value of the new insecticide for codling moth control. These reports were discounted in the United States. They seemed too good to be true.

For use as a liquid spray on fruit trees and vegetable crops, DDT is formulated as a wettable powder containing 50 per cent of the active ingredient. For dusting row crops DDT is ordinarily applied in a formulation containing 5 per cent of the active ingredient. Attaclay, an aluminum magnesium silicate, is quite generally used in 50 per cent DDT concentrates; talc in most of the low concentration dusts.

Approximately 2½ million pounds of 50 per cent wettable DDT were used on orchard crops in the state of Washington in 1949. This replaced some 15 million pounds of lead arsenate and cryolite previously used on tree fruits.

DDT has now replaced the rotenone dust formerly used for pea weevil control on dry edible peas in the Palouse country, and on green peas grown for processing in the Blue Mountain area. On the Washington potato crop, grown mostly in Yakima, Kittitas, Whatcom and Skagit counties, DDT is now used for flea beetle and aphis control, replacing the calcium arsenate cryolite and rotenone formerly applied.

All told, in terms of 50 per cent wettable DDT, Washington state uses close to 4 million pounds of this insecticide annually. Approximately 35 million pounds of technical DDT were produced in the United States in 1948.

Effects on Mankind

Reports on DDT poisoning to man seem to be confined to men working at the spray tank, handling the insecticide in the form of a 50 per cent wettable powder. Apparently, the bronchial tubes are affected, resulting in a persistent cough which ordinarily will disappear in three week's time. This may not be due to the technical DDT, but to auxiliary materials used in the formulations.

Exposure to DDT does not result in any skin irritation, except in case of large quantities, according to Arnold J. Lehman, U. S. Food and Drug Administration. "Solutions of DDT, however, are absorbed and multiple exposures to solutions representing 9 grams of DDT, spilled on the skin or clothing, may represent a quantity dangerous to man."

Quoting Lehman, symptoms of poisoning in experimental animals "usually begin as tremors of the muscles of the head and neck. The tremors progress caudally and increase in intensity with time so that eventually purposeful movements are difficult or cannot be accomplished. Frequent episodes of tonic and clonic convulsive seizures manifest themselves. These convulsive seizures occur with increasing frequency, becoming almost continuous. A stage of depression is eventually reached, terminating in respiratory failure and death. An uncomplicated case of poisoning in man has not been reported, but from the meager information available it appears that giddiness, nervous tension and involuntary muscular tremors are some of the symptoms."

Most of the 50 per cent wettable powders are formulated with some clay in a finely divided form as a diluent. Consequently, a 50 per cent wettable powder may contain nearly one-half aluminum silicate.

Toxicologists report little or no effect of DDT in dermal applications or on the respiratory organs. According to the Washington State Department of Health, it is very unlikely that a man working at the mixing tank will get a fibrotic condition of the lungs (silicosis) due to the short period of exposure and the composition of the carriers and diluents.

Early in 1949, sensational articles written for New York papers inferred that millions of people were being slowly poisoned by the widespread use of DDT. Following a meeting in Washington, D. C., attended by a hundred representatives of various government agencies, a statement on the DDT hazard to human health was issued under date of April 1, 1949. The paragraphs quoted herewith are from this statement.

> DDT is a very valuable insecticide which has contributed materially to the general welfare of the world. It has been used with marked success in both the control and prevention of such insect-borne diseases as malaria and typhus, and of insects which are destructive to crops and injurious to livestock and infest homes.
>
> It is well recognized that DDT, like other insecticides, is a poison. This fact has been given full consideration in making recommendations for its use. There is no evidence that the use of DDT in accordance with recommendations of the various federal agencies has ever caused human sickness due to the DDT itself. This is despite the fact that thousands of tons have been used annually for the past four or five years, in the home and for crop and animal protection. However, minor toxic symptoms may be produced

by kerosene and various solvents used in DDT and practically all other insecticidal mixtures.

Statements that DDT is responsible for causing the so-called "virus X disease" of man and "X disease" of cattle are totally without foundation. Both of these diseases were recognized before the utilization of DDT as an insecticide.

Effect on Wildlife

During 1947 and 1948 many dead game birds were found in eastern Washington orchards. At first it was thought that these birds had been killed when heavy concentrations of TEPP had been applied to control mites, either by the use of fog machines or by airplane. Using mist sprays at concentrations ten times those normally applied in orchard practice, Dr. E. H. Peterson, Associate Veterinarian, State College of Washington, was unable to kill young chickens or nearly mature Chinese pheasants in the laboratory. Likewise, Ralph W. Mohr, State Department of Game, has exposed caged pheasants in orchards where TEPP was being applied with a fog machine, without killing the birds.

Because of so many reports of dead game birds found in orchards, the Washington State Department of Game assigned Mr. Mohr, one of their game biologists, to look for dead game birds in orchards and to find out the spray schedules in those orchards where these were observed. During these 2 years, some 750 cases of dead game birds and song birds were studied. At the present time the evidence points to chronic DDT poisoning, rather than to other new insecticides employed in Washington orchards. Of the song birds, robins were particularly susceptible to orchard sprays.

In north Idaho in 1947, some 400,000 acres of forest lands were sprayed with DDT to combat an outbreak of the tussock moth. This effort was rated as entirely successful, since at the end of the season practically all tussock moth caterpillars in the treated area had been killed. Applications were made as a liquid spray by airplane. Technical DDT, 1 pound, was used in a solvent with a light fuel oil to make 1 gallon of spray.

Used at the rate of 1 pound technical DDT per acre, no ill effects were observed in wild or domestic animals. Rainbow, eastern brook, and cutthroat trout in the 40 streams in the treated area suffered no apparent ill effects. On the other hand, insect larvae were practically eliminated from streams in the area, and an examination of trout stomachs indicated a 50 per cent reduction in available food and a change in diet to include more crustacean forms. Crayfish mortality in sprayed streams was heavy.

Effect on Honey Bees

Beekeepers in the lower Yakima Valley were much concerned when potato growers went over to the use of DDT on a large scale to control flea

beetles and aphids. Previously the bee men had suffered heavy losses in this area when calcium arsenate dusts had been used. Although DDT is definitely toxic to honey bees, the general use of this insecticide on potatoes did not serve to aggravate the problem of bee poisoning. As a matter of fact, less poisoning occurred when DDT was used than before.

Two reasons may be given for this condition of affairs: (1) DDT as applied is less toxic to honey bees than calcium arsenate, and (2) beekeepers have learned to meet the problem by moving yards to new locations at the first sign of poisoning.

Application of a 10 per cent DDT dust, 20 pounds to an acre, has actually increased alfalfa seed production, in spite of the fact that DDT is toxic to honey bees. The reason for greater seed production is that the DDT killed Lygus bugs, sucking insects that sap the vitality from alfalfa plants and lower seed production accordingly. By putting on the dust before blooms appear, the Lygus bugs are killed off, while honey bees escape poisoning since no bees are likely to be present at that time.

The hazard to honey bees in the general use of DDT evidently depends on the crop involved and the time of application. Where an alfalfa field in Utah was dusted while in bloom with 3 per cent DDT, 28 per cent of the field force was killed in colonies of bees located just outside the field, according to observations of Frank E. Todd and associates. The insecticide was applied with a power duster at a time when no field bees were at work.

A repellent effect on the bees was evident in the case of the DDT dusted area. While many bees were actually killed by the insecticide, the visitation of bloom by unaffected field workers was depressed, cutting down on further mortality.

Effect on Other Insects

When DDT was first used experimentally in the Pacific Northwest, it was soon learned that its use in apple orchards led to an increase in woolly apple aphids and orchard mites. Increase in woolly aphis likely is due to killing off the parasite Aphelinus, introduced into Washington in 1931 by Messrs. Newcomer and Yothers, Bureau of Entomology and Plant Quarantine laboratory, Yakima, and by LeRoy Childs, Oregon Experiment Station at Hood River, in 1928. Following the introduction of Aphelinus, the woolly apple aphid was rarely seen for nearly 20 years. With a DDT program this insect is back where it was before the parasites were introduced.

Orchard mites have become more of a problem on tree fruits where DDT has been used. Whether this is due to any effect on natural enemies, or simply to a failure to kill mites, is not clear. One of the most efficient natural enemies of the Pacific mite, the tiny black lady beetle, Stethorus, easily succumbs to applications of DDT.

In Novia Scotia in 1944, DDT sprayed apple trees showed almost complete reduction in numbers of a predacious mite, said to be the most efficient predator of the European red mite in that province, according to F. T. Lord, Dominion Entomological Laboratory, Annapolis Royal.

Resistance to DDT

Failure of residual deposits of DDT to control houseflies was first noticed in 1947, according to Dr. E. F. Knipling, Bureau of Entomology and Plant Quarantine. Most of the failures were encountered in places where DDT had been applied for 2 or 3 years previous.

Following the widespread use of DDT by the armed forces overseas to control flies and mosquitoes, state-wide campaigns were conducted to kill houseflies. After 2 or 3 years, however, the quantity of insecticide that was quite sufficient the first year, failed to produce similar results. It became evident that all the houseflies were not killed in some of the early applications, and that resistant strains of the insects had developed, much more difficult to kill with DDT.

Experiments conducted at Orlando, Florida, where DDT was first studied in the United States, showed that after thirty-six generations, DDT-treated flies required twice the amount of insecticide to kill most of the insects as compared with the first generation. After forty-three generations, three times the quantity of DDT was required to kill most of the flies, as compared with that needed at first. Bred with other houseflies that have not been subjected to DDT sprays, these resistant flies in turn produce others that lose this resistance factor, according to workers in the Bureau of Entomology and Plant Quarantine laboratory at Orlando.

Early in 1948 reports of failures of DDT residual sprays to control houseflies were current in southern California. Similar reports came in from Idaho, where a campaign for a "fly free state" had been under way since 1947.

At first there was a tendency to lay the blame on the insecticide itself. Chemical analyses, however, indicated no significant differences in DDT content in samples of the insecticide produced over a period of 3 years beginning in 1946, according to work by R. L. Metcalf and Ralph D. March, California Experiment Station at Riverside.

These investigators found DDT-resistant strains of houseflies wild in the field near dairies where residual sprays had been applied for approximately 3 years. One of these strains was so resistant that it was practically impossible to knock down and kill 100 per cent of the flies with residual deposits of DDT.

In Virginia, Dr. W. S. Hough, who first demonstrated the resistance of the codling moth to lead arsenate sprays, is quoted as follows: "We have no scientific evidence that the codling moth has developed resistance to DDT."

Similar observations have been made by W. J. O'Neill, Tree Fruit Experiment Station, Wenatchee.

In Indiana, DDT has been used in one orchard for five succeeding years, or fifteen generations of the codling moth, and there is no evidence that the pest in this orchard requires any more DDT to control it than in previous years, according to L. F. Steiner, Bureau of Entomology and Plant Quarantine. It may be that the codling moth will in time show some resistance to DDT. In a recent issue of the "American Fruit Grower," Steiner says, "We believe that long continued usage of DDT in an orchard will eventually lead to the development of strains of codling moth that can tolerate larger amounts of DDT than needed at present for control."

Residues on Sprayed Crops

In 1945, the Food and Drug Administration established a tolerance on DDT of .05 grain per pound. This is usually expressed as 7 parts per million. Washington apple growers have had no difficulty in meeting this tolerance when applications of DDT for codling moth control are restricted to the first brood, even without washing.

Late applications of DDT, applied a week or so before harvest, are impossible to clean to a point below the federal tolerance. Ordinarily, however, applications late in the season are unnecessary, unless those put on earlier have been faulty due to poor timing or adverse weather conditions.

It has been particularly difficult to remove DDT from the surface of apples with the solvents ordinarily used to remove spray residues. When the residues at harvest exceed 10 parts per million, it is ordinarily impossible to remove DDT to a point below the tolerance, according to Kenneth C. Walker, Assistant Chemist, Tree Fruit Experiment Station, Wenatchee.

Loss of the insecticide due to weathering does not seem to be much of a factor, at least in the irrigated regions of the Pacific Northwest where the annual rainfall is less than 10 inches, very little of which takes place during the summer months. Increase in size of fruits during the growing season makes it possible to meet a tolerance of 7 parts per million, since early applications of DDT ordinarily may be depended upon to control most insects affecting tree fruits.

The appearance of the oriental fruit moth in the lower Yakima Valley has brought about the need for spraying with DDT to check that insect on soft fruits, especially in peach orchards. Early applications present no residue complications. Because of increase in size of fruits, 30 parts per million on small peaches would amount to much less than 7 parts on the ripened crop.

It was not until the fall of 1948 that larvae of the oriental fruit moth were found commonly in a limited area in the lower Yakima Valley. Present indications, based on one year's experience, indicate that the insect may be held in check on soft fruits by the use of early applications of DDT. Whether

this may be accomplished year in and year out, remains to be seen.

No residue problem is involved when dry peas or peas grown for processing are sprayed or dusted with DDT. However, there is a hazard to human health when pea forage is fed to dairy cattle, because of the danger of the accumulation of the insecticide in milk. The same thing is true of alfalfa treated with the insecticide to control Lygus bugs or other insects.

Butter made from milk, the source of which was seven dairy cows that had been fed on alfalfa hay previously sprayed with DDT, was found to contain 65 parts per million of DDT, according to investigations reported by Smith, Hoskins, and Fullmer in California. The animals were fed for approximately 3 months. The DDT residue on the hay amounted to 7 or 8 p.p.m. during the feeding. After the first few days, the DDT content of the milk remained steady at about 2.3 to 3.0 p.p.m. Milk production was not affected, nor were there any apparent ill effects on the animals concerned.

Data of this kind support the attitude among entomologists that DDT should not be used as an insecticide where alfalfa or pea forage may be fed to dairy cattle.

Accumulation of DDT in Soil

At first it was assumed that DDT would break down fairly quickly in orchard soils already containing 4 or 5 tons of lead arsenate per acre after years of spraying. This notion likely was due to the fact that little DDT remains on apples at harvest, following application earlier in the season to control the codling moth.

At the present recommended concentrations, approximately 40 pounds of DDT (actual) are being added per acre annually to orchard soils in the irrigated regions of the Pacific Northwest. This estimate likely is too high. It assumes the necessity of three cover sprays for the codling moth. Many growers have found that adequate control may be obtained with two applications.

If DDT does not break down in orchard soils, continued applications over a period of years will aggravate a condition already serious because of the quantity of arsenic now present in these soils. That it persists in the soil is indicated by work of M. C. Lane, Bureau of Entomology and Plant Quarantine, who found that DDT will kill wireworms in soil even after 5 years, following applications at the rate of 10 pounds (actual) per acre. While 10 pounds per acre does not appear injurious to plant life, the application of that much or more over a period of years may be quite a different story.

Soil samples in California citrus groves, where 75 pounds of DDT per acre have been applied for 2 years, indicate a residue in the top 3 inches amounting to 45 parts per million.

Tomatoes planted on land treated the previous year with 40 pounds of

DDT have showed injury at Davis, California, according to observations of Lange and Carlson, California Experiment Station. No effect of the treatment was evident the following year, however, either on tomatoes, potatoes, or lima beans.

Tomatoes grown under glass and treated with DDT have developed serious foliage injury, according to California investigators. When applied to growing tomato plants for the control of insect pests, no injury to commercial fields has been observed in California, according to Michelbacher and his fellow workers.

Use on Apples and Pears

Not until 1946 was DDT available for use on agricultural crops in the United States. In 1947 most Washington apple growers went over to a DDT program and probably 90 per cent of the acreage in eastern Washington was sprayed with DDT to control worms. The general use of DDT has produced crops with so few worms that fruit growers no longer consider worm control as much of a problem.

Because DDT does not control orchard mites and aphids, other insecticides must ordinarily be added. Some of these are good acaricides, effective against mites, but which fail to check infestations of the woolly apple aphid and the green apple aphid. Because parathion kills both mites and aphids at the same time, it is generally used in combination with DDT.

The following paragraphs are from the report of the 24th meeting, Western Cooperative Spray Project, held in Portland, January 5-6-7, 1950.

Codling Moth Control.

1. The following program is suggested for codling moth control.

1st application - 2 lbs. 50% wettable DDT	Applied just prior to the hatching of the eggs.
2nd application - 1 lb. 50% wettable DDT	Timing of these sprays will depend on degress of infestation, weather conditions and other factors.
3rd application - 2 lbs. 50% wettable DDT	

This program is modified as conditions warrant.

2. Effective control of codling moth is dependent on thoroughness of application. Overspraying should be avoided to reduce the rate of accumulation of DDT in the soil and excessive DDT residue on fruit.

3. Due to the variations in climatic conditions and species of mites in the area covered by these suggestions, no single spray program for codling moth and mite control can be outlined.

4. The advantages of a DDT program may be nullified by failure to control mites. The inclusion of an acaricide in all DDT applications is usually necessary. A successful program is dependent on preventive measures. Control is difficult after a severe infestation develops.

5. The use of DDT for codling moth control may be expected to result in an increase in the population of woolly apple aphid, which will in turn increase damage from perennial canker.

6. The program suggested under 1 above should present no residue problem, providing the last spray is applied not later than 30 days before harvest.

7. Lead arsenate or cryolite, or other materials, may be used by those wishing to avoid the complications arising from the use of DDT.

Use on Peas

Previous to 1947, large quantities of rotenone dust were used in the Pacific Northwest to combat the pea weevil. It was estimated in 1944 that 770,000 pounds of rotenone (5 per cent raw root) were needed to protect dry edible peas and canning peas from weevil attack. On dry edible peas, DDT was used on 90 per cent of the crop in 1947. The swing to DDT was due for the most part to lower costs, although control was somewhat more effective because DDT persisted on the vines over a longer period following applications.

Application of insecticide dust for weevil control is made at blossom time. DDT is applied as a 5 per cent dust at the rate of 20 pounds an acre, mostly with ground dusters.

The following recommendations concerning the use of DDT on peas were made at the "Pea Insect Work-shop Section" at the meeting of the Northwest Vegetable Insect Conference, held at Portland, Oregon, January 24-25, 1949:

> Pea Weevil. The committee suggests the following for pea weevil control: 15-20 pounds of 5 per cent DDT dust per acre applied in the same manner and under the same conditions as previously advised for rotenone. The use of DDT is not recommended where pea ensilage or pea hay is to be fed to dairy cattle or to livestock being finished for slaughter. On areas where pea ensilage or pea hay is to be fed, rotenone dusts are recommended.

The only change made at the meeting of this Conference in January

1950 was to suggest the use of methoxychlor for pea weevil control where crop residues may be fed to dairy cattle or animals being finished for slaughter. See Page 17.

Pea Aphid. Practically all the newer insecticides on the market in 1948 have been tested for control of the pea aphid. Of these, only the following can be suggested for pea aphid control:

(1) DDT dust applied at 40 pounds per acre. In some studies the effectiveness of the material is increased by the addition of 50 per cent or more of sulfur or of 0.5 per cent of light, saturated summer oil to the dust mixture. The use of DDT is not recommended where pea ensilage or pea hay is to be fed to dairy cattle or to livestock being finished for slaughter.

(2) TEPP (See Page 26)

(3) DDT in oil. 4-5 per cent of DDT in a light oil base applied at a rate not to exceed 4-5 gallons per acre applied by airplane has given satisfactory control. This material should not be applied to fields on which sulfur has been used. DDT should not be applied to fields where the vines are to be fed to dairy cattle and to livestock being finished for slaughter.

(4) Caution. (a) DDT oil should not be applied to peas that are in blossom and which are not growing vigorously, because of its harmful effect on the blossoms and foilage. (b) Under certain conditions, TEPP sprays and DDT oil sprays may cause burn and burn-like symptoms.

Equipment. Ground dusters give excellent control if kept in good condition. However, dusting equipment needs further improvement. Airplane spraying has been satisfactory, but airplane dusting has not been generally satisfactory.

It is of utmost importance that airplane spray applications be flagged at about a 40 foot swath width for a full boom sprayer, and that the spraying be done at the lowest practicable elevation above the vines (as low as 2-3 feet where possible). Control is reduced by nearly half under otherwise similar conditions where applications are made at 20-25 feet.

Use on Potatoes

In Washington, potato growers had been using calcium arsenate and cryolite for the control of flea beetles previous to 1946. When DDT became available to growers generally, this insecticide replaced both the above-named materials. The greatest advantage of DDT on potatoes is that it assures control of flea beetles, Colorado potato beetles, aphis and leaf hoppers, all at the same time.

In the seed growing area of western Washington the general use of DDT has been followed by a decided lowering of the amount of leaf roll carried by several species of aphids affecting the potato plant. According to the report, Division of Inspection and Seed Certification, State Department of Agriculture, 65 per cent of the seed crop in western Washington in 1945 failed to pass the "blue tag" regulation indicating freedom from leaf roll. During 1945, the standard control for insects and disease was the calcium arsenate-monohydrated copper sulfate-lime dust.

When DDT became available in 1946, even in limited quantities, many growers used this for potato insect control in place of calcium arsenate, following the excellent results obtained by Loyd Stitt, Western Washington Experiment Station, in his experiments conducted in Snohomish County. In 1946 only 20 per cent of the potatoes grown for seed in northwest Washington failed to qualify for "blue tags."

DDT became generally available in 1947, and potato seed growers in northwest Washington used DDT on the entire acreage. Aphis control was so good that in 1947 only 1.7 per cent of the seed crop failed to qualify for blue tags.

Although aphis abundance has been reduced to low levels in fields receiving from four to six applications of DDT in the Yakima Valley, this has not been followed by a corresponding decrease in leaf roll. Had Yakima County potato growers carried out the thorough-going dusting operations over the entire potato growing area, as practiced by seed growers in northwest Washington, leaf rool incidence may have been much further reduced than was actually the case.

In 1947, practically the entire potato crop in the Yakima Valley was dusted with DDT. Many potato growers owned ground dusters and used these, but approximately 50 per cent of the acreage was dusted by airplane, according to B. J. Landis, Bureau of Entomology and Plant Quarantine laboratory at Union Gap.

Ground dusting is necessary for really effective control of aphids in potato fields. Dusting by airplane may suffice to control flea beetles, but after all is said and done, it is not possible to obtain as good coverage from the air as by the use of ground equipment.

Potatoes grown in irrigated lands in eastern Washington often suffer damage from wireworms. DDT applied at the rate of 10 pounds (actual) per acre has reduced wireworm population in the soil to a point where they cause very little damage, according to investigations conducted under the direction of M. C. Lane, Bureau of Entomology and Plant Quarantine, Walla Walla, Washington. The DDT is applied in the form of a 50 per cent wettable powder, broadcast over the soil and thoroughly worked in 6 to 9 inches deep, preferably before planting. One 10 pound application may last for 5 years. Few wireworms are killed the first year, however.

Use on Cranberries

In former years, large quantities of rotenone and pyrethrum were required to protect the cranberry crop in western Washington from attack by two serious insect pests, the cranberry fireworm and the fruitworm. In bogs severely infested by the fireworm, it was sometimes necessary to make as many as eight applications at the rate of 400 gallons of spray material per acre.

With the advent of DDT, D. J. Crowley, Superintendent, Cranberry Experiment Station at Long Beach, found that the use of the new insecticide made possible a higher degree of control than ever before, with half the number of applications. Present spray recommendations are for two applications of DDT in the hook stage of the blossoms, applied at the rate of 2 pounds (50 per cent wettable) per 100 gallons of spray. Because of possible residue complications, no DDT is recommended after the cranberries have formed.

Cranberry growers were advised in 1949 to shift to a program where methoxychlor is used in the after-blossom sprays. Because of its low toxicity to warm bloods, methoxychlor may be used after full bloom. With a DDT-methoxychlor program, it is possible to cut down the number of sprays to three in cranberry bogs where insect infestation has previously been reduced to a low level.

RHOTHANE: This insecticide may be very useful when late applications are necessary on small fruits. Manufactured by Rohm and Hass, Rhothane is being used on the West Coast, especially for tomato insects in California and for the orange tortrix in the Pacific Northwest.

Chemically similar to DDT, this compound lacks one chlorine atom. Dichloro-diphenyl-dichloroethane is the accepted chemical name, usually abbreviated to DDD and sometimes called "triple D". It is also known as tetrachloro-diphenyl-ethane (TDE). Rhothane is available as the technical pure material, as an insecticide concentrate, in the form of an emulsion concentrate, oil soluble solution, a dust concentrate, and a wettable powder.

Effect on Warm Bloods

Rhothane is slightly irritating to the skin, according to Arnold J. Lehman. Symptoms of poisoning "fall in the category of lethargy. Careful observations have not revealed convulsions, although these can be elicited by administering the poison intravenously."

The fatal dose "is about ten times larger than that of DDT, which would place the total quantity at about 8-10 ounces of the solid material. The first symptoms of poisoning occur within 24 hours, with death within 48-96 hours after ingestion."

Experimental animals that "survive after the 96th hour usually recover completely."

Residue Hazard

The proposed tolerance on Rhothane is 5 parts per million. In western Washington where three applications of this insecticide were made on red raspberries, residues on fruit did not exceed 2 parts per million when the last spray was put on 1 month before harvest; approximately 5 parts per million when the last treatment was 2 weeks from harvest; around 12 parts per million when the last spray was applied immediately before harvest.

Growers who may be forced to apply this insecticide because of the occurrence of larvae of the orange tortrix shortly before harvest would be taking chances on residue, should the tolerance be set at 5 parts per million.

Tomatoes grown for canning in California, and washed before processing, showed insignificant amounts of residue. This was also true of the juice extracted from these tomatoes. Higher concentrations of residues were present in the pomace or residue from fruit extraction, according to investigation of Michelbacher, Middlekauff, et al., California Experiment Station.

No information is available as to its toxicity in orchard soils. Because of a lower degree of toxicity of fish and wildlife, Rhothane has some advantage over DDT when used on a large scale for mosquito control.

Use on Small Fruits

Rhothane definitely has a place in combating the orange tortrix, a caterpillar that has become a serious pest of raspberries and blackberries in western Washington. Injury to foliage by the tortrix larvae is insignificant. The insect is important because the larvae drop into boxes at picking time and so contaminate the fruit when it is ready for processing.

In fields where the orange tortrix was known to be common the previous year, an application of Rhothane, 2 pounds (50 percent wettable) per 100 gallons of water, is recommended about May 15.* At least 150 gallons are needed for an acre of raspberries.

Where the orange tortix has been kept well under control, this treatment may be delayed until about June 1. Should larvae be at all common after this date, an application about June 15 may be necessary. Two weeks should be allowed, however, between the time of the last application and the date of first picking, according to entomologists at the Western Washington Experiment Station. This is to avoid any dangerous residue on the picked fruit.

Rhothane cannot be used with oil as a sticker. Experience in western Washington has shown that when oil is used, raspberries promptly develop a chlorosis. If the treatment is repeated several times, the condition becomes

*Or cryolite, 3 or 4 pounds per 100 gallons.

chronic and the injury may be severe, according to E. P. Breakey and Carl Johansen.

Other uses

Used experimentally in western Washington for flea beetle control on potatoes, Rhothane was quite as satisfactory as DDT, according to Loyd Stitt, Western Washington Experiment Station. Seven applications were made with 5 per cent concentration in both cases. A fixed copper was used for disease control, and a 1 per cent petroleum oil added to each dust to hold down the drift.

In California Rhothane has been effective in controlling the eye-spotted bud moth on prunes, according to A. D. Borden, California Experiment Station. Rhothane is now being used on nearly 100,000 acres of tomatoes in California, according to the manufacturers of that insecticide. Most of the serious insect pests of the commercial crop were readily controlled, and in case of the tomato horn worm, results with Rhothane generally were more effective than DDT.

Investigations under the leadership of Michelbacher and co-workers, California Experiment Station, indicate effective control of tomato insects with not more than three applications. On an acreage basis, Rhothane was applied at the rate of 3 pounds of the 50 per cent wettable powder in 100 gallons of water. Thirty pounds of the 5 per cent dust was sufficient.

Investigations at Wenatchee indicate a degree of control for codling moth inferior to that of DDT, used at the same concentrations and number of applications, according to W. J. O'Neill. No control of mites or woolly aphis was apparent.

Rhothane is recommended for leaf rollers on apples in Virginia, using it in place of DDT in the first cover spray and again as a special treatment for leaf rollers in early or mid-July. The shift to DDT for codling moth control in eastern states has been accompanied by an increase in numbers of the red-banded leaf roller, formerly held in check by lead arsenate sprays.

METHOXYCHLOR: Described as the methoxy analog of DDT, this new insecticide is far less toxic to warm-blooded animals (1/24 as toxic), and may find a place for general use on small fruits and other crops where insecticides are likely to result in toxic residues. Dimethoxy-diphenyl-trichlorethane is the best known chemical name for this insecticide. It is also called dianisyl trichlorethane.

Technical methoxychlor is described by the duPont Company as a white solid containing 88 per cent of the above named compound and 12 per cent related materials. Insoluble in water, methoxychlor is soluble in many common solvents used in industry.

Formulated as a 50 per cent wettable powder, methoxychlor is available under the trade name of Marlate (duPont) and Orthotox (California Spray Chemical Company).

Toxicity to Warm Bloods.

Methoxychlor is only slightly irritating when applied to the skin, according to Dr. Arnold J. Lehman. It is doubtful whether an individual would swallow enough methoxychlor to cause poisoning, because of the large amount necessary to produce toxic effects. Lehman estimates the fatal dose for man "to be in the neighborhood of 450 grams (1 pound) if ingested at one time."

Effect on Honey Bees

According to Paul M. Eide, who conducted experiments with methxychlor several years ago in Yakima, this insecticide showed only slight toxicity when fed to honey bees in a mixture of honey and water. Where the bees were forced to crawl over a surface treated with methoxychlor, it proved highly toxic. At that, hazard to honey bees was definitely less than with DDT.

Use on Growing Crops

At the Northwest Vegetable Insect Conference held at Portland, Oregon, in January, 1950, a 5 per cent methoxychlor dust, used at the same rate per acre as DDT, was suggested for pea weevil control wherever crop residues may be fed to dairy cattle or animals being finished for slaughter.

Methoxychlor is now recommended exclusively for after-blossom sprays on cranberries, according to D. J. Crowley, Superintendent, Cranberry-Blueberry Experiment Station at Long Beach, Washington. These applications are for both the fireworm and the fruitworm, following one spray of DDT. Two applications of methoxychlor, 2 pounds (50 per cent wettable) per 100 gallons of water, should be sufficient.

Methoxychlor, 2 pounds per 100 gallons of water, may be used to control the orange tortrix on raspberries when the infestation is not discovered in the berries until nearly harvest time. According to Breakey and Johansen, Western Washington Experiment Station, the residue on the fruits with methoxychlor will persist for only 4 or 5 days, while that of Rhothane will last for about 2 weeks.

Used at the Tree Fruit Experiment Station at Wenatchee, methoxychlor was found to be less effective than DDT for codling moth control, according to W. J. O'Neill. Its use on apple trees resulted in a serious outbreak of both mites and woolly aphids; comparable with DDT plots in the same orchard.

Methoxychlor has showed up well in tests in western Oregon in 1948 and 1949, when applied both as a spray and in dust form to control the cherry fruit fly, according to S. C. Jones, Associate Entomologist, Oregon Experiment Station, Corvallis, Oregon.

In the lower Yakima Valley, the use of 5 per cent methoxychlor dusts for fruit fly control in 1949 was "an over-all failure," according to Kenneth E. Frick, Washington Agricultural Experiment Stations. On the other hand, " Two sprays of methoxychlor, 3 pounds of 50 per cent wettable powder per 100 gallons spaced 10 days apart gave good control in a mixed orchard inter-planted with apricots and peaches, which were not sprayed." On cherries grown for the fresh market, there was a visible residue from the two sprays--which may be a limiting factor in the use of the insecticide to control cherry fruit fly.

Methoxychlor may prove a substitute for DDT to combat house flies where these insects have developed resistance to DDT. Federal entomologists claim that methoxychlor is the most effective and long lasting of any of the analogs of DDT and is more effective to flies than to mosquitoes.

Use on Dairy Cattle

Formulated as a dairy cattle spray in a wettable powder, methoxychlor has a more rapid knock-down action on insects than DDT. The residual effect may last 3 weeks or more when applied to the animals themselves; 6 or 8 weeks when used in dairy barns. Danger of contamination of milk is very low, according to the du Pont Company who manufacture this insecticide.

Eight pounds of methoxychlor in 100 gallons of water is the recommendation of the du Pont Compnay to control horn flies and fleas on warm blooded animals. For cattle lice, more difficult to kill, 16 pounds is recommended.

For the control of house flies, horn flies, mosquitoes, fleas, and cockroaches around farm buildings, the recommendation is 1 pound in 2½ gallons of water. At this concentration, 1 gallon is sufficient for 1000 to 1500 square feet, used "as a residue spray to areas frequented by these insects, such as walls, ceilings, stanchions, cracks, crevices and pens."

According to the du Pont Company, "in some states as little as 8 pounds in 100 gallons of water may be used."

Following are several paragraphs quoted from a press release from the U. S. Department of Agriculture dated March 24, 1949.

> DDT should not be used for insect control on dairy cows, the entomologists of the U. S. Department of Agriculture announced today. Even small amounts of DDT is a food such as milk, a universal diet especially for infants and small children, might prove harmful in time, toxicologists of the Food and Drug Administration, Federal Security Agency, now say after several years of study. They say presence of the chemical in milk would be contrary to the Food, Drug, and Cosmetic Act.
>
> The entomologists now recommend that methoxychlor, another

effective insecticide, he substituted for DDT to control insects pests on dairy cows.

Federal entomologists make no change in their recommendations for the use of DDT in controlling insect pests on other livestock, including beef cattle.

Department of Agriculture entomologists, chemists, and veterinarians, cooperating in the investigations on the toxicology of DDT and other insecticides, say that application of DDT directly to milk cows for controlling insects results in the presence of small quantities of the insecticide in the milk. They say also that DDT in small quantities can be detected sometimes in milk following ordinary use of the insecticide for fly control in dairy barns.

The Bureau of Entomology and Plant Quarantine has repeatedly cautioned that forage treated with DDT and other chlorinated hydrocarbon insecticides should not be fed to dairy animals or to livestock being finished for slaughter.

A number of new insecticides are under investigation by Department entomologists for controlling insects on milk cows and in dairy establishments. Methoxychlor, one of the new chlorinated hydrocarbon insecticides, can be used satisfactorily in the same way as DDT on dairy cattle for controlling major insect pests such as horn flies, stable flies, and lice. Little or none of this insecticide appears in milk of dairy cattle when it is applied to the animal in amounts necessary to control the insects. The Food and Drug Administration has stated that methoxychlor, used in place of DDT for this purpose, is unobjectionable from the health standpoint.

Compatibility

The following statement is made by the du Pont Company under date of July 1, 1949:

> Methoxychlor is compatible with most commonly used fungicides, such as wettable or dusting sulfurs, Bordeaux mixture, the low solubility (or "fixed") copper compounds, and the newer organic fungicides, the dithiocarbamates.

DIMITE is a trade name for one of the chlorinated hydrocarbons formulated by the Sherwin-Williams Company which has shown considerable promise for control of orchard mites on the West coast. A close relative of DDT, this compound is sometimes known as DMC, the letters evidently taken from the chemical name, di (p-chlorophenyl) methyl carbinol. More specifically, this acaricide is designated as 1, 1, bis (p-chlorophenyl) ethanol. The commercial product contains 25 per cent of the active ingredient.

According to the manufacturers, "Data concerning toxicity to human

beings indicate that DMC is less toxic than DDT." Approximately 15,000 gallons of DMC was available in the Pacific coast states in 1949.

Used at the rate of 1 pint in 100 gallons of water, excellent control of Pacific mites has been obtained with DMC at Yakima, according to a report by Dean and Newcomer, published in the Proceedings of the Washington State Horticultural Association for 1948. Two or three applications were needed for the Pacific mites, and also "controlled the European red mite very well."

According to these writers, "Even a single application, put on about the middle of July, controlled the Pacific mite very well, but it was not effective enough to hold the European red mite in check for the rest of the season. No injury has been observed." When used in apple orchards, the main limiting factor is the failure to control the woolly apple aphid.

Mite control was outstanding at the Hood River Experiment Station in 1948, where the Willamette mite is the predominate species, according to LeRoy Childs and Vernon Olney.

DMC has shown up well in control of European red mites and two-spotted mites, according to A. D. Borden, California Experiment Station. Ovicidal properties and a rather long residual value are listed by Borden as characteristic of this acaricide. No injury has accompanied its use on apples and pears in California.

NEOTRAN, a Dow Chemical Company product, formerly known under the code number K 1875, is another acaricide closely related to DDT and used to a limited extent in the Pacific Northwest. Chemically the product is known as bis (p-chlorophenoxy) methane.

Formulated as a wettable powder, Neotran contains 40 per cent of the active ingredient. It is reported to be only 1/10 as toxic to warm blooded animals as DDT, and like DDT, is not readily absorbed through the skin.

Claimed to be toxic to mite eggs as well as to the active stages, Neotran has proven to be a good acaricide, although when used in apple orchards in the Pacific Northwest, it has had little or no effect on woolly apple aphids.

Two applications of Neotran, 2 pounds per 100 gallons, afforded "excellent control of the European red mite, and a single application on July 7 kept populations of this mite at a lower average level for the rest of the season than any other material used," according to investigations of Dean and Newcomer at Yakima in 1948. These writers state that Neotran controls the European red mite better than it does the Pacific mite. Because of russeting, especially on Yellow Delicious, 2 pounds is not recommended by the manufacturers.

At Wenatchee, two applications of Neotran on Red Delicious, 1 pound per 100 gallons, applied in the pink and first cover spray, held mites in check

until mid-July, according to investigations of W. J. O'Neill, Tree Fruit Experiment Station. An additional spray applied August 3 afforded good control of European red mite, but poor control of Pacific mite.

So far the main limiting factor in the use of Neotran on apples has been the tendency to cause a russeting on the surface, particularly on such varieties as Golden Delicious. Because of russeting on Anjous and Bartlett pears, Neotran is not recommended on pears.

TETRAETHYL PYROPHOSPHATE: Cut off from their normal supply of nicotine as an insecticide during the last war, German scientists worked on several of the organic phosphates as substitutes. Captured enemy reports indicated that one of these phosphates, known as Bladan, was particularly efficient for the control of aphids and mites, even more so than nicotine alkaloid itself.

Research chemists in the United States later found that the active ingredient in Bladan was not hexaethyl tetraphosphate, as claimed by the Germans, but another phosphate ester best described as tetraethyl pyrophosphate. Consequently, the real value of commercial preparations depends on the tetraethyl pyrophosphate content.

Early formulations contained from 12 to 20 per cent tetraethyl pyrophosphate. According to "Agricultural Chemicals," the technical material now being offered generally is 40 per cent of the active ingredient. The remaining 60 per cent consists of unreacted triethyl phosphate and ethyl metaphosphate. Labels usually state that the material contains 40 per cent tetraethyl pyrophosphate and 60 per cent of other ethyl phosphates.

Tetraethyl pyrophosphate $(C_2H_5O)_4P_2O_3$ is a colorless, mobile liquid, miscible with water, acetone, alcohol, benzene, carbon tetrachloride, and other solvents. It is not miscible with kerosene, petroleum ether, or other paraffinic oils. It decomposes at temperatures above 135°C. (275° F.) and has a specific gravity of 1.2.

The chemical is said to be effective for mites and aphids even at dilutions of one to 10,000. Toxicity of tetraethyl pyrophosphate decreases rapidly in the presence of moisture. A 1 per cent solution may lose 90 per cent of its toxicity within 24 hours.

Laboratory and field tests of TEPP dusts in southern California indicate that a specially calcined pumicite (Frianite H. P.) mixture used as a carrier delayed decomposition of tetraethyl pyrophosphate for a longer period than other carriers investigated, according to Maxwell and Swain. The addition of a stabilizer further prolonged the period of insecticide effectiveness.

Dust formulations should be used immediately. Anhydrous calcium sulfate is used in formulating TEPP dusts, in order to retard decomposition, according to R. H. Robinson, chemist, Oregon Experiment Station. Other dehydrating chemicals may also be used.

For the most part TEPP is formulated with a solvent and emulsifiers so that the commercial product has a content of 20 per cent tetraethyl pyrophosphate. California Spray Chemical Company handles this insecticide under the trade name of Vapotone. The Lucas-Kiltone people use the trade name Tetratone. Monsanto Chemical Company manufactures this insecticide using the trade name Nifos. Bladex is the name given to the Shell Oil Company product. Eston Chemicals, Inc., formulate this insecticide under the trade name Tetron. Hexamite, the product offered by Niagara Chemical Division, Food Machinery and Chemical Corporation, contains 40 per cent tetraethyl pyrophosphate.

Toxicity to Warm Bloods

"Acute toxicity studies on rats, mice, and rabbits have shown that tetraethyl pyrophosphate is extremely poisonous to warm blooded animals when introduced orally or absorbed through the skin," according to John S. Harris, Monsanto Chemical Company. "The immediate gross toxicity when administered orally to rats in a water solution is approximately 2 mg./kg. of body weight; by intraperitoneal injection, the LD/50 to mice is approximately 0.7 mg./kg.; and less than 0.04 ml. will cause death when placed on the abdominal skin of a rabbit. These tests cannot, of course, be extrapolated directly to humans, but certainly a high degree of toxicity may be expected."

The following paragraphs on the toxicity of this insecticide are taken from a report on Industry and Government Cooperative Studies, prepared in the Bureau of Entomology and Plant Quarantine, Washington, D. C., and released under date of June 10, 1948.

> Toxicology. Tetraethyl pyrophosphate is an extremely toxic material readily absorbed through the skin. The Division of Pharmacology of the Food and Drug Administration reports: "The LD/50 for a single acute exposure on dermal application is 10 mg/kg. In terms of a human being, an estimated fatal dose is approximately 600 mg. On repeated application, this dose is halved." The hazard of formulated insecticides has not been studied, but the foregoing illustrates how toxic small quantities may be, especially when it is realized how readily tetraethyl pyrophosphate is absorbed. In the interest of safe use, the following cautions are suggested:
>
> 1. Avoid contact with the skin, especially when handling the concentrated material. Gloves impervious to tetraethyl pyrophosphate should be worn. If skin is accidentally contaminated, wash carefully with soap and water immediately. Individuals should be required to keep shirts buttoned to the neck, sleeves down and buttoned at the wrist.
>
> 2. Avoid the inhalation of tetraethyl pyrophosphate mist, dust, or aerosol by wearing a respirator or mask approved by the United States Bureau of Mines.

3. Adequate personal hygiene and cleanliness of the operator are necessary. At the end of the operation the clothing should be removed, followed by a thorough bath with warm water and soap.

4. Avoid contamination of food; smoking, eating, and chewing tobacco should be prohibited in the operating areas.

5. Any persons developing symptoms of headache or tightness of the chest when using tetraethyl pyrophosphate should be removed from the exposure. In the case of ingestion of tetraethyl pyrophosphate, an emetic such as mustard or warm soap water should be used immediately and the patient referred to a physician.

Atropine has been found a physiological antidote but should be administered under medical supervision.

The following information on the toxicity of organic phosphates to human beings is taken from a paper by Dr. Herbert K. Abrams, California Department of Public Health.

> The organic phosphates attack the gastro-intestinal tract and have interesting, possibly serious, effects on the nervous and muscular systems. They seem to attack the blood enzyme known as cholinesterase. As a result, excess acetyl choline accumulates, producing symptoms of excessive parasympathetic stimulation. The chemical also apparently stimulates the myoneural junction in a manner similar to that of nicotine. The result is the worker exposed to this material displays marked contraction of the pupils to the point of blindness, dyspnea with feeling of tightness of the chest due to spasm of the bronchial tubes, and in severe cases a pulmonary edema resulting from dilation of the capillaries and excessive glandular secretions in the bronchi and bronchioles. The smooth muscle of the intestinal tract becomes spastic, causing vomiting, abdominal cramps and other abdominal symptoms. The central nervous system is affected, causing excitement and sometimes convulsions. Death and acute poisonings may be due to any one of the following mechanisms: bronchial constriction and cardiovascular collapse; central nervous system stimulation and eventual depression of the neuromuscular junctions; and accidents occurring as a result of visual or mental impairment.

According to Leslie E. Hildebrand, M.D., a practicing physician at Wenatchee, most of the ill effects observed from insecticides in orchards in that area result from exposure to tetraethyl pyrophosphate. Common symptoms are soreness of the nose and throat. On occasion, the bronchial tubes are affected, resembling somewhat a virus type of pneumonia.

Airplane pilots applying this insecticide in dust form find that the chemical gets into the eyes, affecting vision. This occurs when the chemical seeps up into the cockpit from below, or when it is necessary to fly through a cloud of dust. Even when protected by gas masks, pilots have trouble when the goggles fog up in early-morning applications of TEPP dust. Often times the mask is thrown off because the pilot cannot see clearly and exposure to the insecticide results.

The pupils of the eyes may be reduced to a pinpoint following exposure to the insecticide, according to Dr. Hildebrand. Pilots affected in this manner are advised to avoid further exposure to tetraethyl pyrophosphate. When the insecticide is applied by plane in liquid form, effects of this kind have been much less frequent.

TEPP dust amounting to 1 1/4 million pounds was sold in the Wenatchee district in 1948, according to A. R. Rolfs.

Hazards to human health in the use of this material were discussed at a meeting of public health officials, insecticide men, and others, February 17, 1947 in Olympia. This followed reports of shortness of breath, apparently due to constriction of the bronchial tubes, experienced by spray men making applications of TEPP as a liquid spray with ground equipment and as an aerosol with fog machines. Because of these reports, especially in the Wenatchee district, the matter of restricting the use of the insecticide was seriously considered by the State Department of Health. Formulators of the material presented evidence at the Olympia meeting, however, indicating that many growers had used TEPP, often being exposed to it for hours at a time, without any ill effects. Consequently, no action was taken to restrict its use in Washington orchards.

The acute oral toxicity of tetraethyl pyrophosphate to warm-blooded animals is far more than that of DDT, even more than that of parathion, according to Dr. Arnold J. Lehman, U. S. Food and Drug Administration. Comparisons based presumably on the technical materials indicate that tetraethyl pyrophosphate is 125 times as toxic as DDT. Parathion is listed as 70 times as toxic as DDT on the same basis.

Effects on Operators

Washington fruit growers encountered difficulty in the application of this insecticide with conventional ground equipment when first used, because of ill effects on the operators. Formulators of the insecticide recommended that persons susceptible on account of tightness of chest, painful vision, or nausea be removed from the job. Such ill effects and reported damage to plungers in spray equipment in turn led to the use of airplanes and fog machines in place of ordinary ground equipment.

Residue Considerations

Because TEPP is rapidly decomposed following its use as an

insecticide, and because the known decomposition products are not considered a health hazard, the residue problem on fruits and vegetables is practically nil. Diethyl acid phosphate is said to be the chief decomposition product following hydrolysis.

Use on Tree Fruits

Formulations of this insecticide have been used in large quantity in Washington since 1947 to control mites on tree fruits. As was anticipated, when growers went over to a DDT program, mites became abundant on tree fruits, frequently requiring special applications to hold them in check.

The following paragraphs are from the report of the 24th meeting, Western Cooperative Spray Project, held in Portland, January 5-6-7, 1950.

TEPP:

1. Tetraethyl pyrophosphate has given control of some species of mites.

2. Due to the lack of residual action, careful timing of these sprays is necessary.

3. Concentrations will range from 1/4 to 1/3 of a pint of 20 per cent material per 100 gallons of spray.

4. Tetraethyl pyrophosphate is highly toxic to man and animals, and every precaution given by the manufacturer should be used in handling this material. Read the label.

5.. Tetraethyl pyrophosphate applied during slow drying conditions has given some injury to fruit.

Liquid application by airplane has been faulty because ofthe tendency of the insecticide to hydrolize, breaking down before reaching the foliage for which it was intended. Reports on the use of dust by airplane are conflicting. Irregular distribution and drifting of the dust are the most serious limitations.

Application in fog machines afforded irregular results, mostly due to lack of uniform coverage. Some damage to foliage occurred, evidently due to high concentrations close to the machine. Serious injury to the foliage and fruits of Anjou pears has occurred in British Columbia, according to James Marshall, Dominion Entomological Laboratory, Summerland, B. C. This occurred at concentrations as low as 1 to 4000, applied with conventional ground equipment. This may be due to the particular formulations involved, since this injury was not characteristic of all brands of TEPP used in British Columbia. Very little TEPP is used in British Columbia, according to Dr. Marshall.

Use on Peas

The following recommendation concerning the use of TEPP on peas for aphis control was made at the "Pea Insect Work-Shop Section" at the meeting of the Northwest Vegetable Insect Conference, held at Portland, Oregon, January 24-25, 1949:

> TEPP experimental evidence is limited, but field observations indicate that TEPP sprays applied by airplane at the rate of 1 pint of 40 per cent or 1 quart of 20 per cent of the toxic ingredient in 10 gallons of water per acre will give reasonably good control. Dusts containing 1 per cent of TEPP applied at the rate of 40 pounds per acre by ground equipment has also given good control.
>
> The use of TEPP is hazardous. Extreme care should be taken in its use by all persons connected with its application. Airplane pilots should be especially cautious because of its effect on vision. Ground crews should also be protected by gas masks and rubber gloves.

Use on Hops

Hop growers in eastern Washington used TEPP in 1948, mostly as a 1 per cent dust to kill aphids and mites. Ground applications were made at the rate of 35 to 40 pounds per acre. When applied by airplane 50 to 60 pounds were necessary to obtain adequate coverage, according to E. C. Klostermeyer, Irrigation Experiment Station, Prosser.

Hop aphids not only feed on the vines, but also affect quality. Honeydew secreted by the aphids sticks the hops together, interferes with drying, and serves as a culture medium for the growth of sooty mold.

Even more serious is the fact that hops may be contaminated with dead aphids and subject to seizure by the federal Food and Drug Administration.

To be effective, any insecticide for hop aphid control should be applied prior to the burr stage of the hops. Where adequate control has been obtained before or up to the time of flowering, hops in eastern Washington "remain free or nearly free of aphids for the rest of the season and no aphids got into the cones," according to Mr. Klostermeyer.

Five sheep were killed on a neighbor's farm near Grandview, Washington, in 1947, having been exposed to drift from a fog machine in a hop yard, according to information received from the Washington State Department of Health.

Use on Potatoes

In eastern Washington, on potatoes a special application of TEPP or

nicotine is recommended for the specific purpose of killing aphids after the vines mat the rows. This is most effective if applied "prior to the time of development of winged aphids whose later flights may otherwise increase the rate of spread of leafroll within and between fields." Forty pounds of 0.5 per cent tetraethyl pyrophosphate dust per acre, applied by airplane, is recommended. "Ordinarily this application should be made between June 20 and July 1 for the early crop."*

Use on Broccoli

Used at the rate of 35-40 pounds per acre, a 1 per cent TEPP dust has proved effective for the control of aphis in western Washington. In fact, good results have been obtained with concentrations as low as 0.5 per cent, according to Loyd Stitt, Western Washington Experiment Station. Some residual effect was evident with TEPP in this connection, since few differences were observed between TEPP and parathion. Aphids on broccoli have always been particularly difficult to control.

Where the cabbage worm needs special treatment on broccoli, a TEPP-rotenone mixture is recommended, 0.75 per cent rotenone being combined with the TEPP dust.

PARATHION: an organic phosphate, available for experimental use first in 1947, has been found very effective in controlling orchard mites and aphids on tree fruits in the Pacific Northwest. Developed in Germany during the war, at least one plant was in commercial production of parathion as an insecticide in Europe as early as 1947. Some 600,000 pounds of parathion were used on tree fruits in Washington in 1949.

Technical parathion is said to contain 95 per cent or more of the pure chemical, 0,0-diethyl-0-p-nitrophenyl thiophosphate. The chemical is an ester of thio-phosphoric acid having the empirical formula of $C_{10}H_{14}NO_5PS$. A liquid varying from deep brown to yellow, some samples have a characteristic foul odor. Its boiling point is said to be 375°C., or higher.

Parathion is only slightly soluble in water (20 p.p.m.). It is completely miscible in such organic solvents as the alcohols, ketones, ethers, aromatic hydrocarbons, animal and vegetable oils. It is practically insoluble in petroleum ether, kerosene, and refined petroleum oils used as sprays.

Parathion is stable to hydrolysis in distilled water, even in hard water containing as much as 650 p.p.m. of dissolved solids and in acid solution. It is rapidly hydrolyzed in the presence of alkaline materials such as lime, sodium hydroxide, lime sulfur, Bordeaux mixture, or calcium arsenate with an excessive lime content.

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*Circular No. 69. Washington Agricultural Experiment Station. February, 1949.

Toxicity to Warm Bloods

Published figures on the extreme toxicity of parathion to warm bloods are misleading because they are based on the technical material itself. Commercial formulations contain either 15 per cent or 25 per cent technical parathion as a wettable powder. Dust formulations contain 2 per cent parathion or less.

Toxicological investigations have shown that parathion formulated as a wettable powder is actually less toxic than liquid formulations of the technical product. According to the American Cyanamid Company, the mean lethal dose (acute oral toxicity) for albino mice is 6.0 mg/kg for the chemical itself. Incorporated as a wettable powder, the M. L. D. is 21 mg/kg. In other words, $3\frac{1}{2}$ times as much parathion was needed to obtain the same results when a wettable powder was used. Both figures were calculated as actual parathion contained in the formulations.

Male albino rats were fed parathion for a period of 60 weeks to determine any chronic toxicity over that period. At the end of the last week, those rats whose food contained 50 p.p.m. weighed on an average, 399 grams; 100 p.p.m., 384 grams; controls, 383 grams. In other words, there was no loss in weight to these rats following daily feeding on a diet that contained as much as 100 p.p.m. of parathion.

At first it was thought that parathion would accumulate in animal tissues, but more recent investigations point otherwise. Writing to the National Canners Association February 16, 1949, Dr. Arnold J. Lehman, Chief, Pharmacology Division, Food and Drug Administration, stated that parathion is not stored in animal tissues to any appreciable extent. Moreover, it is rapidly destroyed by these tissues, in turn an added mechanism to prevent tissue accumulation.

While there may be no actual accumulation of parathion, there may be an accumulation of the effects of the poison following continual exposure. Parathion is said to attack the blood enzyme known as cholinesterase. Continued depletion of this enzyme by repeated exposures may result in toxic effects as discussed on Page 23.

In orchard investigations, parathion has been used at very low concentrations. The chemical as supplied for experimental use in 1947 contained 15 per cent technical paration as a wettable powder. That supplied later contained 25 per cent parathion. During the 1949 season,60 per cent of the parathion supplied in the Pacific Northwest was the 15 per cent wettable, while the remainder was the 25 per cent material.

Effects on Honey Bees

Definitely toxic to honey bees, a 1 per cent parathion dust killed 40 per cent of the field force during some experiments in Utah by Frank E. Todd and associates when an alfalfa field was dusted while in bloom. In fact, there

was some evidence that hive bees were also killed by the insecticide, since on the second day after application a conspicuous number of bees were observed crawling around the hives and behaving as if poisoned. The use of parathion on orchard trees likely would not affect honey bees, unless the bees were visiting a cover crop in bloom at the time of application.

Effects on Operators

Experience of growers in using parathion in the late summer of 1948 indicated that precautions must be taken to avoid nausea, headache, or sore hands. According to W. J. O'Neill, there was one report of headache "resulting from handling and mixing the concentrate material in a building without precautionary measures." Several cases of nausea were reported by one concern formulating parathion dust:

> It was reported by several individuals that they had chapped, dry, sore hands after working and spraying with the material. In these cases the men would wear rubber gloves while handling the concentrate in filling the spray tank after which they would remove the gloves while spraying.

Investigations with parathion at the Tree Fruit Experiment Station and cooperative work with growers in the Wenatchee district have not been accompanied by any ill effects on the operators, according to Mr. O'Neill. One grower in the Wenatchee Valley reported that "he had a severe headache and pain in his eyes after closely following a speed sprayer application for some time with no precautions." This man had completely recovered by the following morning.

Symptoms of parathion poisoning include headache, blurred vision, dizziness, weakness, nausea, cramps, diarrhea, and discomfort in the chest.

Atropine is an antidote for parathion poisoning. If any of the above symptoms develop while using parathion, atropine should be given immediately. Call the doctor at once.

A prescription is necessary to obtain atropine. Where operators are exposed to parathion, arrangement should be made with a physician for a small supply to be used only in an emergency.

Never handle parathion with bare hands or wearing leather, cloth, or synthetic rubber gloves. If it is necessary to handle the insecticide, wear natural rubber gloves. Avoid exposure to spray or dust drift during application. Avoid breathing or skin contact when opening original packages.

Wash hands, face, and arms after handling parathion and before eating or smoking. Change clothing immediately and bathe thoroughly with soap and water whenever you come in contact with parathion, either in concentrated or diluted form.

Parathion is very toxic to warm blooded animals, either as a 15 per cent or a 25 per cent concentration. Some authorities believe there is less hazard involved to operators in the use of the lower concentration. Either is dangerous, especially if carelessly used!

Read the precautions printed on the package. Anyone unable or unwilling to use these precautions should avoid handling parathion entirely.

Most gas masks are uncomfortable to wear. Consequently, they are usually discarded, even by operators engaged in mixing organic phosphates at the spray tank.

Mine Safety Appliances, Pittsburgh, Pennsylvania, manufacture a respirator with replaceable cartridges and filters especially recommended by the American Cyanamid Company, the principal producers of parathion. The respirator and replacement parts are identified as follows:

Parathion respirator, Mine Safety Appliances Co. No. CR 49290
Replacement cartridges, Mine Safety Appliances Co. No. CR 49293
Replacement filters, Mine Safety Appliances Co. No. CR 49294

The following paragraphs are taken from The Occupational Health Bulletin, California Department of Public Health, dated October 1949.

> A preventive program which has been proposed by some of the manufacturers of parathion consists, in part, of the following:
>
> The field use of bulk wettable concentrates should be banned. Maximum size package for field use should be 5 pounds.
>
> Use of liquid parathion formulations should continue to be prohibited.
>
> Dusts for field use should be limited to 2 per cent parathion.
>
> The retail sale of parathion formulations for home use should be prohibited.
>
> Approved sift-proof bags or containers should be used for field distribution of all wettable concentrates.
>
> Sale of straight technical parathion should be limited to fully qualified manufacturers and blenders.
>
> Treatment - Atropine is a specific drug for combating the effects of the organic phosphates. Large doses (1/75 to 1/50 of a grain or 1 mgm.) should be given early and repeated frequently if necessary. Any exposed person developing symptoms of headache, nausea, diarrhea,

difficulty in breathing or in seeing, should immediately be removed from the exposure and seen by a physician. His clothes should be changed and exposed skin washed with soap and water. If there is difficulty in breathing, the patient should be placed in a position with his chest lower than his trunk so that excess bronchial secretions will drain out, and artificial respiration given. If available, oxygen should be administered while waiting for the arrival of a physician.

Fatalities due to Parathion

Three men engaged in the manufacture or the formulation of parathion as an insecticide were killed during 1949. These men were exposed to concentrated materials, remained at work even after symptoms of toxic effects were noticed, and failed to take such precautions as change of clothes and bathing after exposure.

Three more men killed during the application of parathion as an insecticide to growing crops. One man in North Carolina was killed following the use of parathion in a tobacco field in a mule-drawn cart sprayer. In this case, the concentration was 4 pounds of the 25 per cent wettable powder in 100 gallons of water. This man walked behind the sprayer and was exposed to the mist all day long. His clothing became soaked with the spray material. According to reports, he had not been informed of the risks involved.

Late in August 1949, a skilled worker died following the use of parathion experimentally on a planting of navel orange trees at Riverside, California. Here again, the 25 per cent wettable powder was used at the rate of 10 pounds to 500 gallons of water. The speed sprayer used for application of the insecticide was loaded 17 times during the day.

This man changed clothing during the lunch hour, although he had not been exposed to excessive spray drift earlier in the day. Although he complained of a headache at noon, this was not severe. Returning to the spray operations after lunch, he wore coveralls in addition to a cap, boots, and gloves.

Shortly after 4 p.m. this man informed his co-worker that he felt dizzy. A few minutes later be became nauseated, vomited, and left for home immediately. On his way home, he became violently nauseated and had to ask another young man to drive him home. He reached home at approximately 4:45 p.m. Fire department personnel administered oxygen prior to the arrival of a physician. The doctor arrived shortly after 5 o'clock, but the man was dead at approximately 5:05 p.m.

In this case, continued exposure at the time the wettable powder was added to the spray tank may have been mainly responsible for his death. According to one report, the parathion was observed to blow up into the man's face while being placed in the tank.

Although this man had previously worked with parathion and other organic phosphates, there were no indications that he was particularly sensitive to these materials. Familiar with the hazards involved, it is not believed that he was knowingly careless in handling the parathion.

The third case was that of a man in Florida engaged in loading speed sprayers with 25 per cent parathion wettable powder. Six pounds of the powder and 50 pounds of wettable sulfur was the concentration added to 500 gallons of water. Although this man had previously encountered ill effects from the use of parathion, the statement is made that he stirred the parathion and sulfur with his bare hands in order to force the material through the screen. In the Florida case, the man had gross skin contact and inhalation exposure to the wettable powder.

No respirators were used by any of these three men. In orchard practice or field application, it is difficult to force operators to do so regardless of the nature of the poison concerned. Although ill effects due to overexposure to parathion have been observed in the Pacific Northwest, no fatalities have occurred.

Labels

State and federal authorities believe that all products containing parathion in any amount should carry precautionary statements with the skull and cross-bones and the word "Poison" in red on a white background.

While preparations containing less than 2 per cent of parathion may not be considered as highly toxic to human beings and thus not require the skull and cross-bones on labels, warning statements are necessary on all labels.

Residues on Fruit

Because of the high toxicity of parathion to warm-blooded animals, Food and Drug officials have been concerned about its use on fruits and vegetables. Without making any attempt to minimize its poisonous nature, two factors should be pointed out: (1) the low concentrations at which parathion is effective in controlling aphis and mites, and (2) the rapidity with which parathion breaks down following its use as a spray.

The following data are taken from an abstract of a paper by Kenneth C. Walker, Assistant Chemist, Tree Fruit Experiment Station, Wenatchee, given at a symposium on Economic Poisons, American Chemical Society, March 27-April 1, 1949, at San Francisco.

> Jonathan, Delicious, and Winesap apples sprayed with varying concentrations (0.5 to 1 pound) of 15 or 25 per cent wettable powder per 100 gallons carried a parathion residue ranging from 0.000 to 0.14 p.p.m., when analyzed 29 to 104 days after harvest.

One pound per 100 gallons of water of the 25 per cent wettable powder of parathion applied to Bing cherries, Moorpack and Tilton apricots, Italian and Hungarian prunes, and Elberta, Golden Jubilee, and J. H. Hale peaches resulted in parathion residues on the surface of the fruit, 30 days or more after harvest, that ranged from 0.00 to 0.08 p.p.m. When the fruit was analyzed less than 30 days after application the parathion residue ranged from 0.08 to 1.63 p.p.m.

Legal tolerances for insecticides on fruits and vegetables going into interstate commerce are established only after public hearings. According to present information, the probable tolerance on parathion likely will be 2 parts per million.

Use on Apples and Pears

The following paragraphs concerning parathion are from the report of the 24th meeting, Western Cooperative Spray Project, held in Portland, January 5-6-7, 1950.

1. Concentrations will range from 1/2 to 1 lb. of 25 per cent wettable or from 3/4 to 1.5 lbs. of 15 per cent wettable powder, depending on the species involved and the extent of the infestation.

2. Parathion is highly toxic to man and animals, and every precaution given by the manufacturer should be used in handling this material. Read the label.

3. Wettable powders present the least hazard of any form in which parathion may be used.

4. Parathion in oil has the highest toxicity to man and animals and should not be used.

5. Parathion sprays should not be applied less than 30 days before harvest because of the possible residue.

6. Applications of parathion as a dust are not suggested, because of the health hazard.

Parathion is the most effective chemical we have found for the control of orchard mites and aphids in the Northwest over a period of 20 years of research.

Parathion may be useful in combating pear psylla. A dormant application in the Entiat Valley, 1 pound of 25 per cent wettable to 100 gallons of water, killed both eggs and adults practically 100 per cent, according to W. J. O'Neill.

In the Washington recommendations for spraying apples and pears in 1949, the following statement is made on the use of summer applications of parathion for the pear psylla:

> For summer control of the pear psylla, use parathion wettable powder, 5 ounces of 25 per cent or 1/2 pound of 15 per cent to 100 gallons of water. For adequate control, two summer sprays about a month apart should be applied, adding the parathion to the DDT used for controlling the codling moth. If a dormant spray of oil has been applied, it may not be necessary to use parathion for pear psylla in the first cover spray. Sprays should be timed so that the second application comes about a month or 6 weeks before harvest.

While parathion, at present costs, is too expensive to use for worm control in apple orchards, 1 pound of the 25 per cent wettable material will hold the codling moth in check for approximately 3 weeks.

Use on Stone Fruits

Parathion, 1/2 to 1 pound of the 25 per cent wettable powder or its equivalent in 100 gallons of water, has given good control of most species of aphids on stone fruits. Thirty days should lapse between an application of parathion and the time of harvest to avoid residue complications.

Mites on stone fruits may be controlled by using parathion 1/4 to 1/2 pounds of the 25 per cent wettable powder in 100 gallons of water. The first application should be made as soon as the mites become evident on foliage.

The adult shot-hole borer may be controlled by spraying the infested trees with 1 pound 25 per cent wettable parathion plus 1 pound of 50 per cent wettable DDT, according to observations of E. W. Anthon, Tree Fruit Experiment Station, Wenatchee. Applications of this combination should be made late in May or when the peak of adult beetle activities can be observed on the infested trees. Larvae of this insect are not controlled by these insecticides.

Compatibility

Parathion is compatible with wettable powders and dust blends of DDT, BHC and toxaphene, with rotenone, pyrethrins and with wettable and dusting sulfurs. It may be combined with insoluble coppers and with insoluble metal salts of dithiocarbamic acids. Fuller's earth and any of the pyrophyllites may be used as diluents, as can diatomaceous earth and any of the bentonites, provided the pH is below 8.5. Sufficient information is not yet available as to its stability in alkaline media such as hydrated lime, Bordeaux, and lime sulfur, according to the American Cyanamid Company.

BENZENE HEXACHLORIDE: This is one of the most effective insecticides investigated by entomologists in the last 10 years. The greatest drawback is

the musty odor frequently taken up by fruits and vegetables, rendering these distasteful for human consumption. While benzene hexachloride is the term now generally used to designate this particular compound, it may be more properly referred to as hexachlorocyclohexane, since the chlorine molecules are attached to a cyclohexane ring rather than to a benzene ring.

Benzene hexachloride is a white crystalline compound with the empirical formula of $C_6H_6Cl_6$. It is prepared by the chlorination of benzene in the presence of actinic light. It is stable in the presence of acids, but decomposes in the presence of an alkali.

Five isomers have been identified and given names: alpha, beta, gamma, delta, and epsilon. The insecticidal value of benzene hexachloride depends mostly on the content of the gamma isomer, which is far more toxic to insects than any of the others. Technical benzene hexachloride may contain from 5 per cent to 28.5 per cent of the gamma isomer.

Because off flavor imparted to fruits and vegetables was the chief limiting factor in the use of technical BHC, studies were undertaken to determine the role played by the various isomers through a research program made jointly by the Bureau of Entomology and Plant Quarantine and of Human Nutrition and Home Economics, U. S. Department of Agriculture, and the California Spray-Chemical Company. As reported by S. A. Rohwer in a recent issue of Agricultural Chemicals, "Delta and beta isomers applied to portions above ground, or mixed in the soil, imparted a foreign odor or flavor to the edible portion of treated crops more often than alpha and gamma, and the odor or flavor was stronger.

Rhubarb, spinach, broccoli, sweet corn, tomatoes, snap beans, lima beans, and potatoes were dusted three times during the growing season in these trials, using a 10 per cent concentration by weight of each isomer. "In each case, the dusts were applied to the developing fruits or foliage that was to be eaten, except in the case of potatoes."

Additional trials were made in which the various isomers were mixed in a loam soil in three gallon crocks in which potatoes, tomatoes, and lima beans were grown. Finally, wettable powders containing the various isomers were applied to peaches 18 days before harvest.

Benzene hexachloride is available as a wettable powder and in dust form. Originally the wettable powder contained from 6 per cent to 12 per cent of the gamma isomer, together with other isomers, which ran up as high as 40 per cent of the total amount. Benzene hexachloride dusts usually contain 1 per cent of the gamma isomer. These are applied at the rate of 30 to 35 pounds per acre.

Chemical research during the past year has progressed to the point where it is now possible to manufacture the pure gamma isomer in large scale commercial production. For the sake of simplicity, the term "lindane" is now used to designate the gamma isomer of benzene hexachloride. This

coined name is established for the chemical with a purity of not less than 99 per cent. As such, it is a white crystalline substance with a melting point of 112^{o} C.

Insecticides made from lindane are formulated as emulsion concentrates containing 20 per cent of the chemical, and as wettable powders that contain 25 per cent.

Toxicity to Warm Bloods

The following paragraph concerning the toxicity of the gamma isomer is taken from a statement sent out by S. A. Rohwer, Chairman, Interdepartmental Committee on Pest Control, Washington, D. C. dated June 25, 1949.

> Relatively medium order of acute toxicity. Rated by Lehman as being approximately twice as toxic from acute standpoint as DDT, but only one-fourth as toxic from a chronic standpoint as DDT. Lehman and associates have also shown that gamma isomer is eliminated from the body at about the same rate as intake; that it does not accumulate in the system above the level of intake and that shortly after (approximately 1 to 3 weeks) cessation of intake, the gamma isomer completely disappears from the system.

Toxicity to Honey Bees:

Benzene hexachloride is toxic to honey bees in laboratory and field tests in Massachusetts, according to Shaw and Butler. In Skagit County, Washington, where BHC is used in cabbage seed fields during the blossom period, colonies of bees in this area are slow to build up during this time--probably due to exposure to the insecticide.

In an alfalfa seed field in Yakima County dusted with BHC while in blossom to kill aphids, Herman F. Menke observed severe poisoning to honey bees. With an insect net, Menke caught bees on the wing soon after dust was applied. Confined in screen cages, all the worker bees caught died within 2 and 1/2 hours.

Use in Dairy Barns

Lindane was recommended as a residual spray for fly control in dairy barns by entomologists of the U. S. Department of Agriculture in July 1949. It was not recommended for use on dairy cattle or on any forage fed to dairy cattle or animals being finished for slaughter.

If used as a residual spray in dairy barns, the finished product should contain three-tenths to one-half of 1 per cent lindane. To obtain the lower concentration, add $1\frac{1}{2}$ gallons of the 20 per cent emulsion to 100 gallons of water. If the 25 per cent wettable powder is used, add 10 pounds to 100 gallons

of water.

Ordinarily, 1 gallon will treat 500 square feet of surface in a dairy barn. All treated surfaces should be sprayed to the point of run-off. Smooth non-porous surfaces will require the higher concentration (one-half of 1 per cent lindane) to obtain effective residual action.

Lindane sprays have been effective in killing houseflies where resistance to DDT has developed. Applications of lindane are effective from 3 to 6 weeks.

Use on Tree Fruits

One pound of benzene hexachloride (10 per cent gamma content) per 100 gallons of water has afforded control of three species of apple aphids-rosy, green, and woollies-according to W. J. O'Neill, Tree Fruit Experiment Station at Wenatchee. More than one application may be necessary, however.

The use of benzene hexachloride for aphis control in Washington apple orchards has not been followed by off-flavor when applications were restricted to the fore part of the season, i.e., before July 1. Later applications to apple trees, however, have resulted in off-flavor.

In California, where 2 pounds of benzene hexachloride (5 per cent gamma) per 100 gallons where applied to apple trees 3 months before harvest, the fruit was inedible. Gravenstein apples in the Sebastopol area harvested early in July were unmarketable from application of BHC in late May. Again, Newton apples in the Watsonville area, sprayed in June and harvested in October, were tainted before and after storage, according to A. D. Borden, California Experiment Station entomologist.

Investigations at the Dominion Entomological Laboratory, Summerland, B. C., indicate that tainting in tree fruits is "much less pronounced with highly refined 90 per cent gamma isomer than with formulations manufactured from materials of a relatively low gamma isomer content." With unrefined BHC, off-flavor "was much more pronounced in canned than in raw fruit, and slightly more pronounced in stewed fruit."

On soft fruits, benzene hexachloride has been used for the control of peach aphis and black cherry aphis in the Yakima Valley early in the season without affecting the quality of the fruit. Early trials with BHC, where the soil beneath cherry trees was treated to kill maggots of the cherry fruit fly, indicated some degree of control. Later investigations in the lower Yakima Valley in 1949 have not substantiated these results, according to Kenneth E. Frick, Irrigation Experiment Station. Consequently BHC is not recommended as a soil treatment for this insect.

Benzene hexachloride (12 per cent gamma) 2 to 4 pounds per 100 gallons of water, applied to Montmorency cherries in 1948 by S. C. Jones Associate Entomologist, Oregon Experiment Station, but the degree of control of the fruit flies was inadequate, even at the heavier concentrations.

Not only that, but there was a definite off-flavor in all cherries sprayed with this insecticide.

From elsewhere in the country have come reports of off-flavor on canned peaches following the use of benzene hexachloride. In fact, the National Canners Association in 1948 advised their members not to accept any fruit for processing on which applications of this insecticide had been made at any time during the growing season.

Use on Potatoes

Benzene hexachloride is quite effective for wireworms when applied to the surface of the soil and worked in 6 or 9 inches deep with a disk. In eastern Washington, however, root crops take up the musty odor of the chemical.

Benzene hexachloride was used on 60 acre potato field in the Yakima Valley in 1947 for wireworm control, a trial sponsored by one of the insecticide concerns interested in its development. Potatoes from this field were unsalable on account of off-flavor. It has not been recommended for use on potatoes in Washington either by state or federal agencies.

Use on Other Vegetables

The use of BHC on vegetables in western Washington, even the refined high gamma product where the musty odor is slight, has resulted in off-flavor in certain vegetables. While this may be difficult to detect in fresh vegetables, the canned product may have a very definite off-flavor.

In sampling fresh vegetables where 1 pound and 2 pounds of the gamma isomer were used per acre, off-flavor was detected in peas and pole beans, and to a lesser extent in carrots and bush beans, according to Loyd Stitt, Western Washington Experiment Station. Even at the $\frac{1}{2}$ pound level, the off-flavor could be noted in peas.

In frozen products, off-flavor has been detected in broccoli, cauliflower, beans, and corn, according to Mr. Stitt.

Use on Cabbage Grown for Seed

Of all the insecticides tested during the last 10 years, BHC has been almost 100 per cent effective against the cabbage seed pod weevil. Practically the entire acreage in Skagit County has been dusted with BHC since 1947. While off-flavor is not a factor in cabbage seed production, there is the possibility that there may be an accumulation in the soil that would affect such crops as potatoes and peas grown on this land in subsequent years.

In the case of BHC, the problem is one of off-flavor rather than of human health. Processors are well aware of this situation and are keeping their growers informed on the risk involved.

About an acre of canning peas was dusted with BHC to control the pea aphis near Dayton, Washington, by the Blue Mountain Canneries in 1947, according to R. E. Miller of that company. The dusting was from the ground, and was applied when the field was almost out of bloom and was filling pods. The benzene hexachloride was used at the rate of 1 pound of the gamma isomer per acre, and for one application only. The experiment was conducted under the direction of Dr. J. C. Chamberlain, Bureau of Entomology and Plant Quarantine.

About 50 cases of peas from this field were canned, according to Mr. Miller. The off-flavor was medicinal in nature, suggestive of gasoline, and appeared to be concentrated in the cotyledons. It was not a case of the vined peas coming in contact with the insecticide, because peas carefully removed from the pods were just as strongly flavored. The odor of benzene hexachloride was much more noticeable in the lug boxes of peas than it was on the vines.

Beans grown for seed on land infested with wireworms in California have been successfully treated with BHC to control that pest. In 1948, beans grown on more than 10,000 acres in the Sacramento Valley were treated with BHC, cutting down the wireworms in the soil as much as 75 per cent or more. Baby lima bean seed on 25,000 acres was treated in 1949 in California. The planted seed acts as a bait, the wireworms being killed as they move toward the surface of the soil.

Lindane is used in this seed treatment, according to Messrs. Lange, Leach, and Carlson, California Experiment Station. This is available as a 25 per cent wettable powder or as a 75 per cent powder especially manufactured for seed treatment. The following information is quoted from California Agriculture:

> Although technical grades of benzene hexachloride that have characteristic musty odors are effective they should not be used, as they are more likely to injure germinating seeds.
>
> Dosage of lindane for seed treatment has to be considered for each crop. Not only does lindane affect the germination of some kinds of seed more than others, but also its insecticidal efficiency varies with different crops. For example, lindane is used at the rate of two to four ounces of 25 per cent lindane to 100 pounds of seed for baby lima beans, but at 16 ounces of the same mixture for sugar beets.
>
> Fungicides can be safely combined with lindane to form a combination insecticide-fungicide treatment. During studies made at the Experiment Station, the following fungicides used with lindane had no apparent adverse effects: Arasan, Ceresan M, Phygon, Semesan, Spergon, and yellow cuprous oxide.

Seed treatment likely would be necessary every year on heavily infested land. Whether this could be done without danger of causing off-flavor to root crops planted on treated land remains to be seen.

CHLORDANE: In the highly refined state chlordane is described as a viscous, nearly odorless liquid, with a boiling point of 175° C. at 2 mm, pressure and a specific gravity of 1.6. One gallon of this chemical weighs approximately 13.5 pounds. Insoluble in water, chlordane is soluble in the usual organic solvents and completely soluble in kerosene. As an insecticide, this material may function as a result of direct contact, by reason of ingestion or from exposure to its vapor.

Chlordane is available as a liquid concentrate and as a wettable powder. For instance, one company furnishes chlordane for agricultural applications as a 50 per cent wettable powder, a 46 per cent emulsifiable concentrate containing 4 pounds of technical chlordane per gallon, and a 73 $\frac{1}{2}$ per cent emulsifiable concentrate which contains 8 pounds of technical chlordane per gallon. In addition, dust formulations containing as low as 5 per cent or 10 per cent chlordane are available.

Velsicol 1068 is the trade name used by the Velsicol Corporation, following the empirical formula of chlordane, $C_{10}H_6Cl_8$. Julius Hyman & Company manufacture chlordane under the trade name of Octa-Klor.

Penichlor is the term used by S. B. Penick & Company for their various formulations of chlordane, while Toxichlor is the name utilized by the Thompson-Hayward Chemical Company.

Effects on Warm Bloods

Chlordane is moderately irritating to the skin, according to Arnold J. Lehman, U. S. Food and Drug Administration. This property is lost on dilution in insecticide formulations.

The acute oral toxicity of chlordane is about half that of DDT, according to Lehman, i.e. 500 mg/kg. Chronic effects, however, may show a toxicity as much as five times that of DDT.

Chlordane was more toxic than DDT when fed to sheep over a period of 60 days, according to Howard Welch, Montana Experiment Station, Bozeman. Fed to sheep at the rate of 4.5 grams daily (approximately 0.1 gram per kilo), DDT "produced severe symptoms of poisoning at 10 days." Chlordane, 4.5 grams of a mixture of chlordane and xylene (3.5 grams chlordane) "was extremely toxic, and half this dosage proved about as toxic."

Sheep grazed for 21 days on pasture sprayed with chlordane at the rate of 1 pound, and 4 pounds per acre showed no indication of toxic effect, according to Dr. Welch.

Toxicity to Honey Bees:

Applied to an alfalfa field while in bloom at the rate of 22 pounds per acre, a 5 per cent dust killed 23 per cent of the field force of honey bees, according to investigations of Frank E. Todd and associates in Utah. More than 60 per cent of the dead bees were recovered in the field, the remainder close to the hive. Chlordane ranked next to DDT in toxicity to bees.

Not much is known about the residue hazard. According to Julius Hyman and Company, "Chlordane is volatile. When used on crops, all toxic residue evaporates completely at the end of 21 days, when applied in insecticidal concentrations."

Use on Growing Crops

Ten pounds of technical chlordane per acre will kill wireworms in the course of several months and prevent reinfestation of the soil for 2 years, according to workers at the Bureau of Entomology and Plant Quarantine laboratory, Walla Walla, Washington. No recommendation for the use of chlordane for wireworm control will be made until more has been learned about any accumulation of residues in treated soil and effects on soil organisms and plant growth generally.

So far, we have not found chlordane particularly effective for insects affecting tree fruits in Washington. E. J. Newcomer, Bureau of Entomology and Plant Quarantine, found chlordane ineffective for pear psylla control in his investigations made in British Columbia in 1947.

In western Washington, chlordane has given satisfactory results when used to control the cabbage maggot. This was used as a 5 per cent dust applied by hand with a bellows type duster. A single puff from the duster was directed toward the base of each plant, using the insecticide at the rate of 30 pounds per acre. Following a second application in July, the effectiveness of this treatment appeared to persist for a period of from 1 to 3 months.

In addition, control of the carrot rust fly looks promising. On the other hand, chlordane did not satisfactorily control insects affecting the potato crop in western Washington, according to Loyd Stitt.

Recent investigations by federal entomologists indicate that chlordane is most effective for grasshopper control when applied to succulent vegetation where the insects are feeding in large numbers. According to J. R. Parker and Claude Wakeland, Bureau of Entomology and Plant Quarantine, spraying or dusting succulent growth along roadsides, railroad rights-of-way, canal banks, and field margins kills grasshoppers more rapidly than when baits are applied. This results in better control. "On bare ground, dry stubble, or in tall, dry vegetation which is no longer attractive to grasshoppers as food, bait is generally more effective and economical."

Use of ground sprayers or dusters or airplanes assures rapid

application. Even distribution is necessary. Too light an application is ineffective. Forage treated in this manner should not be fed to dairy cattle.

Sprays have afforded better results than dust applications. One pound of technical chlordane is recommended per acre for a liquid spray. For a dust, $1\frac{1}{2}$ pounds of technical chlordane is recommended per acre.

Some 200,000 pounds of chlordane, technical grade, were used for grasshopper control in the state of Illinois in 1948, according to George C. Decker, Illinois Natural History Survey. Most of this was applied as a concentrate in liquid form by airplane. Some of it was spread by means of helicopters. Excellent results were obtained with concentrations of 1/2 to 3/4 pound of chlordane an acre. After mid-August, when vegetation began to toughen up and the grasshoppers reached maturity, 1 pound per acre was recommended.

TOXAPHENE: Originally a trade name used by the Hercules Powder Company for a chlorinated camphene insecticide, that concern has relinquished the trade name so that it may be used as a common name. Properly, the name toxaphene should be restricted to a chlorinated camphene having a chlorine content of 67-69 per cent.

The technical product is an amber, waxy solid with a mild odor suggestive of both chlorine and camphor, and melts between 75 and 90° C. The average empirical formula is $C_{10}H_{10}Cl_8$. It is readily soluble in such commercial solvents as acetone, benzene, fuel oil and kerosene.

Toxaphene is available as liquid spray concentrates that contain 45 per cent and 60 per cent of the technical material. The first named contains 4 pounds of technical chlorinated camphene per gallon; the second, 6 pounds per gallon. Dust formulations are also available, containing 5 per cent, 10 per cent and 20 per cent chlorinated camphene--a 40 per cent spray powder is also available for use as a spray or as a base for making dusts.

Phenacide is the term utilized by the Thompson-Hayward Chemical Company. Geigy Company, Inc., put out a 40 per cent chlorinated camphene under the trade name Gy-phene 40, while the Stauffer Chemical Company uses the names Emtox 45 and Toxadust. Pennsylvania Salt Company formulates a chlorinated camphene in concentrations of 20 per cent and 40 per cent under the trade name Penphene.

Toxicity to Warm Bloods

Lehman rates toxaphene as being four times as toxic to warm bloods as DDT and as having a mean lethal dose of 60 mg. per kilo. Evidently there is much variation. According to the Hercules Powder Company, the mean lethal dose (oral toxicity) for guinea pigs may be as high as 282 mg. per kilo., while the same effect on dogs would require only 10 to 20 mg. per kilo.

According to Lehman, however, rats "can ingest a quantity of the

compound in the course of 24 hours which, if administered in a single dose would be fatal." He continues:

> Chlorinated camphene bears a close chemical relationship to camphor and it is known that camphor is readily detoxified in the liver. It is believed that when the chlorinated camphene is ingested in small amounts over an extended period of time, the detoxication keeps pace with the intake, thus preventing dangerous concentrations from being reached in the body tissues.

In Montana, yearling steers and ewe lambs were fed on alfalfa hay treated with toxaphene, applied at rates that varied from 1 to 8 pounds per acre. None of these animals showed any toxic effects, except in the case of two steers that were fed hay that had received 8 pounds of toxaphene per acre. These animals developed temporary nervous symptoms or muscular tremors but quickly and completely recovered, according to Dr. Hadleigh Marsh, Veterinary Research Laboratory, Montana Experiment Station. Eight pounds per acre is far in excess of recommended concentrations for grass-hopper control.

Effect on Honey Bees

According to the Hercules Powder Company, who first developed toxaphene as an insecticide:

> Field tests on alfalfa in the West indicate that toxaphene dusts applied at the rate of 1.5 to 2.5 pounds of toxaphene per acre caused no decrease in the number of bees visiting the blossoms in treated fields and did not kill sufficient bees to affect the vigor of the hive. In laboratory testing of the relative toxicity to bees of organic insecticides, toxaphene was found to be the least toxic of the nine studied. In spite of the toxaphene's relative lack of toxicity to honey bees, the treatment of crops at peak bloom should be avoided as a precautionary measure.

Dusted on alfalfa while in bloom, toxaphene was found less dangerous to honey bees as compared with DDT, chlordane, or parathion, according to investigations in Utah by Frank E. Todd and associates. Counts were made of dead bees in front of the hives and in strips laid out in the dusted areas, in order to determine the number of field bees killed by the insecticide. In case of toxaphene applied as a 10 per cent dust the mortality was 2 per cent in one case; 8 per cent in another.

Uses for Toxaphene

In his work on pear psylla control in British Columbia in 1947, E. J. Newcomer reported that toxaphene (and parathion) "showed the most promise of any of the materials tested." Toxaphene has also considerable value in

applications for mites and woolly aphis, according to investigations carried out by Newcomer and his associates at the Bureau of Entomology and Plant Quarantine laboratory at Yakima. Three applications of toxaphene, 1 pint (50 per cent to 100 gallons of water afforded excellent control of the Pacific mite. Since toxaphene is compatible with DDT, this combination may be used on pears to control the psylla, mites and codling moth. Toxaphene prevented infestations of woolly aphids from building up in 1948, even when discontinued as early as the middle of July.

Toxaphene controlled the Pacific mite "almost as well as parathion, but is much less effective against the European red mite," according to investigations of Newcomer and Dean at Yakima in 1948.

In New York state, a summer spray of 3 pounds of 25 per cent toxaphene wettable powder per 100 gallons of water is recommended for pear psylla control. Late applications should be avoided, however, because of danger of excessive residue.

Like chlordane, this chlorinated camphene has recently been found quite effective for grasshoppers, especially when applied as a liquid spray. Killing grasshoppers more rapidly than the bran-sawdust-sodium fluosilicate bait, both these new chemicals are particularly effective when applied to succulent vegetation along roadsides, canal banks, and margins of fields, according to investigations of federal entomologists engaged in grasshopper control.

For a liquid spray, $1\frac{1}{2}$ pounds of technical chlorinated camphene is recommended per acre. This should be stepped up to 2 pounds per acre if used as a dust.

Application to range land may be made by ground sprayers or dusters, or by airplane. Dairy animals should not be allowed to feed on forage treated with these chlorinated hydrocarbons.

An insecticide dust composed of 15 per cent chlorinated camphene plus 5 per cent DDT in 40 per cent sulfur has afforded excellent control for the salt marsh caterpillar, an insect that defoliated cotton fields in an outbreak during the season of 1948 in the Salt River Valley of Arizona, according to entomologists of the Federal Bureau of Entomology and Plant Quarantine. This combination is said to be the first that has really given good control of this insect in cotton fields. Previous attempts to control the pest with insecticides have been unsatisfactory.

<u>METHYL BROMIDE</u>: Much used as a fumigant, especially in California, methyl bromide has an advantage because of a low toxicity to growing plants and a high degree of penetration. In industry, its widest use is in the preparation of aniline dyes.

Methyl bromide is a colorless liquid, practically non-inflammable, and has a slightly persistent odor approaching that of chloroform. It has

a specific gravity of 1.732, and a boiling point of 40.1^{o} F. Consequently, methyl bromide is a gas at ordinary temperatures. Liquified at low pressures, methyl bromide is sold commercially in cylinders, even in 1 pound cans.

Methyl bromide is toxic to warm-blooded animals as well as insects. Prolonged exposures, even at concentrations as low as 33 p.p.m., may be followed by severe irritation of the lungs. Concentrations dangerous to human beings may be detected with a halide detector, such as used by refrigeration workers. Careless handling, either as a liquid or a gas, may lead to fatal consequences. Suitable masks should be used when workers are exposed to atmosphere containing methyl bromide. Because the odor is so slight, methyl bromide should be handled with extreme care.

Complete mortality of the olive scale has been reported in the San Joaquin Valley in California when small olive trees and rose bushes were fumigated with methyl bromide in a gas-tight chamber. Exposure was for 2 hours with a concentration of 1 1/2 pounds per 1,000 cu. ft. and a temperature of 80^{o}F. To obtain complete mortality at temperatures lower than 80^{o}, higher concentrations are necessary. Fumigation at 50^{o} afforded irregular results, and was not recommended. At 85^{c} there was danger of injury to plants.

In California, Mackie and his associates found that adults and young of the bulb mite were killed by fumigating with methyl bromide at the rate of 3 pounds per 1000 cubic feet, for 4 hours at a temperature of 70^{o}F. Some of the mite eggs, however, survived this treatment.

At the Western Washington Experiment Station, Dr. E. P. Breakey fumigated croft lily bulbs with methyl bromide at several concentrations and found actual stimulation in growth as compared with cyanide fumigation. Breakey believes that two fumigations, 10 to 14 days apart, using methyl bromide at the rate of 3 pounds per 1,000 cubic feet for 2 hours at 70^{o}F., will effectively control bulb mites on lilies in western Washington.

At a mean temperature of 58^{o}F., methyl bromide was a satisfactory fumigant for the pea weevil in dry peas in fumigation chambers, according to R. D. Eichmann, Washington Experiment Station. This was at a concentration of 1.75 pounds per 1,000 cubic feet and for an exposure of 17 hours. Methyl bromide was unsatisfactory at temperatures below 50^{o}F.

On the other hand, both liquid cyanide and discoid cyanide were effective at mean temperatures of 30' to 40^{o}F., while chlorpicrin was an effective fumigant at a mean temperature of 12^{o}F.

Because of its high penetrating power, methyl bromide has proven useful in the fumigation of stored products, flour, and balled nursery stock. Its use, however, requires a tightly enclosed space to prevent leakage.

ETHYLENE DIBROMIDE: This is a liquid with a boiling point of 132^{o}C. Used for the control of stored grain insects, this chemical is available as a fumigant containing 5 per cent ethylene dibromide. For fumigation in mills, a

formulation containing 15 per cent ethylene dibromide is also available.

Ethylene dibromide is toxic to man even in dilute form, and should be handled accordingly. While there may be little danger out-of-doors, care should be taken not to breathe the vapor.

Severe irritation to the skin may follow prolonged exposure. Wet clothing should be removed immediately. If spilled on the skin, the exposed surface should be washed immediately with soap and water.

For the control of insects affecting grain in farm bins, the ideal time for fumigation is during the early storage season. This kills those insects present at that time. Treatment of grain during August and early September should give protection until the following summer.

Two gallons of the fumigant, containing 5 per cent ethylene dibromide, is sufficient for each 1,000 bushels of grain in tightly constructed bins such as steel ever-normal granary bins. Those of loose construction require more of the fumigant because of leakage. Three to 4 gallons to each 1,000 bushels of grain are necessary for bins that are really not tight.

The fumigant may be sprayed directly on the surface of the grain with a small hand sprayer. Using a length of 1/8 inch pipe without a nozzle, applying from the outside to avoid breathing fumes, is a satisfactory procedure.

For use as a soil fumigant, ethylene dibromide is available in solution in a light petroleum oil. The commercial product contains either 20 per cent or 40 per cent ethylene dibromide by weight. Ethylene dibromide is the best immediate liquid fumigant for the control of wireworms in the irrigated regions of West coast states known at the present time, according to workers in the Federal Bureau of Entomology and Plant Quarantine. This is used at the rate of 10 gallons of a 40 per cent solution per acre.

Most wireworms live from 3 to 15 inches below the surface. Consequently, the ethylene dibromide should be placed at least 8 inches in the soil. Applied from a tank attached to a plow or tractor, the liquid flows by gravity directly to the bottom of the furrow. According to M. C. Lane, practically all the wireworms in the soil are killed at the time of application.

Two weeks should elapse before planting in fall and spring, following soil applications of ethylene dibromide. In summer, this time can be cut down to 7 or 10 days.

<u>ETHYLENE DICHLORIDE:</u> This is a colorless liquid with an odor similar to that of chloroform. It has a boiling point of 83°C. Mixed with carbon tetrachloride in the proportion of three to one, this chemical has some advantages as a fumigant, especially because of its freedom from fire hazard and relatively low toxicity to human beings. Boiling points of the two substances are about the same, and consequently they volatilize at nearly equal rates. Under the name of <u>Dowfume 75</u>, Dow Chemical Company formulates a product described

as "an all-purpose grain and spot fumigant mixture" composed of ethylene dichloride 75 per cent, carbon tetrachloride, 25 per cent.

Vapor of ethylene dichloride has a slight anesthetic action if inhaled. No harmful effects are likely, however, unless exposure is over a prolonged period and at high concentrations. In preparing the emulsion, the work should be done out-of-doors or in a well-ventilated room at temperatures between 50 and 80°F. Both the emulsion and the liquid ethylene dichloride itself should be kept away from fire or an open flame.

Ethylene dichloride has proven useful in killing peach tree borers. This method of control was developed in Georgia by Oliver I. Snapp, Bureau of Entomology and Plant Quarantine and further investigated in the Pacific Northwest by A. W. Anthon. Potash fish-oil soap was first used as an emulsifier, but monothanolamine and triethanolamine have proven more satisfactory. A stock solution of ethylene dichloride may be made up as given herewith, although most growers will prefer to purchase the emulsion already made up.

Ethylene dichloride	100 pounds
Monoethanolamine	1.6 pounds
(or triethanolamine 4.3 pounds)	
Oleic acid	8 pounds
Water	100 pounds ($12\frac{1}{2}$ gallons)

Preparation: In the following method, the ethylene dichloride and water are stirred alternately into the emulsifier made from the monoethanolamine (or triethanolamine) and oleic acid. A rapid mechanical stirrer is desirable to make a stable emulsion. Adequate ventilation should be provided if ethylene dichloride is mixed indoors. Special care should be taken to avoid inhaling the vapor of ethylene dichloride or any contact with the skin.

1. Mix the oleic acid, monoethanolamine, and one-third of the ethylene dichloride, and stir until the mixture is homogeneous.

2. Stirring vigorously, slowly add a volume of water equal to the ethylene dichloride present until a thick creamy emulsion results.

3. Add half the remaining ethylene dichloride in small portions, then half the remaining water while stirring continuously.

4. Add the rest of the ethylene dichloride and the rest of the water in a similar manner. Emulsification is complete when the ethylene dichloride and water are evenly distributed. Prolonged stirring is usually not needed.

Made according to this formula, the emulsion contains approximately 48 per cent ethylene dichloride. A good emulsion should not separate out for 6 months or more. This emulsion is diluted with water according to the table given herewith. From 1/8 to 1/2 pint of the dilute emulsion, according to the age of the tree, is poured around the base of the infested trees, including the trunk. Treatments are made preferably during October, although they can

also be made in the spring. Careful measurements are essential, since excessive applications injure trees.

Age of Trees Years	Water Gallons	Emulsion Gallons	% Ethylene Dichloride	Amount Per Tree Pints
1	$8\frac{1}{2}$	$1\frac{1}{2}$	$7\frac{1}{2}$	1/8
2	7	3	15	1/4
3	7	3	15	1/2
4 & 5	6	4	20	1/2
6 or more small size	6	4	20	1/2
6 or more large size	5	5	25	1/2

PROPYLENE DICHLORIDE: This is a clear, colorless liquid, with an odor similar to that of ethylene dichloride and a boiling point of 95°C. More satisfactory for peach tree borer control because of greater penetration, propylene dichloride appears to be quite as efficient even at concentrations from one-fourth to one-third lower than that required for ethylene dichloride emulsions, according to investigations by E. W. Anthon at Wenatchee. Since the two chemicals cost about the same, preference would be given propylene dichloride.

A stock solution may be made as follows:

Propylene dichloride	100 pounds
Triethanolamine	6 pounds
Oleic acid	14 pounds
Water	100 pounds

So far, experimental work has been conducted on peach trees 3 years old or older. Propylene dichloride is not recommended on young peach trees until further research is accomplished.

A mixture of propylene dichloride (1-2 dichloropropane) and 1-3 dichloropropene, most commonly known under the trade name of DD, is used extensively for the control of nematodes. DD is the name used by the Shell Company to designate their product. Eston Chemicals utilizes the trade name Nemafume, while the Dow Chemical Company uses the name Dowfume N for a similar product.

This fumigant is corrosive and flammable. Equipment used for its application should be made of corrosion-resistant metals. Such equipment should be thoroughly cleansed and flushed with kerosene after use. The fumigant itself should be kept away from open flames. Because of its toxicity to human beings, applicators should not breathe heavy concentrations of the vapor. In contact with the skin, the liquid may cause serious inflammations.

If any of the fumigant is spilled on clothing or skin, the clothing should be removed and the body thoroughly washed with soap and water wherever contacted by the liquid. Whenever spilled on or into shoes, these should be removed and not used again until the odor of the fumigant is all gone.

From 200 to 300 pounds per acre are recommended for nematode-infested soil. The fumigant is injected into the soil in rows 12 inches apart and at a depth of at least 8 inches. Several weeks should elapse before planting. Where 200 pounds per acre have been applied and the soil temperature is above 60°F., there should be a 2 week interval between treatment and any seeding, and 3 weeks in case of transplants For every additional 100 pounds per acre, an additional week should elapse before planting.

DINITRO COMPOUNDS: Combined with petroleum oil, dinitro-o-cresol has been used commercially in Britain where it is said to be particularly useful for destroying aphid eggs. Because of the tendency to injure foliage, both dinitrophenol and dinitrocresol are practically restricted for use during the dormant period on fruit trees.

DNOC is 4,6-dinitro-o-cresol, a yellow odorless solid, practically insoluble in water, with a melting point of 85.8°C. Dinitro-o-cresol has been used to kill hibernating codling moth larvae in the Pacific Northwest. With the general use of DDT and the high degree of control it gives, few codling moth larvae winter over on the trees. Consequently these trunk sprays are now little used in commerical orchards.

Directions for the use of a trunk spray were formulated by the U. S. Bureau of Entomology and Plant Quarantine, following investigations by M. A. Yothers and F. W. Carlson at the Yakima (Washington) laboratory. The spray is applied only to trunks and leaders covering rough bark, cracks, and crotches. Counts showed that the application of this trunk spray destroys 90-95 per cent of the overwintering worms.

Certain derivatives of these dinitro compounds have proved especially efficient against mites. This is true of dinitro-o-cyclohexylphenol, even at very low concentrations, such as half an ounce in 100 gallons of water. DN dust contained 1 per cent of this compound when first manufactured commercially.

In British Columbia, James Marshall has recommended the mono-ethanolamine salt of dinitrocyclohexylphenol for control of the European red mite and the Pacific mite. According to Marshall, this combination "does not appear harmful to insects that destroy orchard mites."

This combination, called "Mono DNP" in British Columbia, is made up by adding 1 ounce of monoethanolamine to 5 ounces of DN dry mix No. 1 in 100 (imperial) gallons of water.

DNOCHP is 2,4-dinitro-6-cyclohexylphenol, a yellowish-white odorless crystalline solid with a melting point of 105° C. The dicyclohexylamine salt, with residual action more prolonged and dust mixtures safer on citrus, has been made available commercially and contains 1.5 per cent of the salt. Dow Chemical Company formulates dusts of this concentration under the trade names DN Dust D-4 and DN Dust D-8.

Pyrophyllite is used as a carrier. The D-8 dust contains about 1.8 per cent mineral oil, which serves to increase the initial depositing properties of the dust mixture and probably serves also as an adhesive agent. In Oregon and Washington, DN Dust D-4 is used mostly on hops. Dn-111 is more concentrated and contains 20 per cent of the dicyclohexylamine salts.

Although its use during high temperatures has been accompanied by serious injury on occasion, DN-111 was recommended for use with DDT to control mites and worms on apples in Washington in 1947 at concentrations of from 1/4 to 3/4 pounds in 100 gallons of spray. Experience has shown that DN-111 is more effective for the control of the Pacific mite than for the European red mite. All things considered, however, 1/3 pound is the safest to use.

The efficiency of DN-111 may be greatly reduced when combined with DDT or methoxychlor and used to control the Willamette mite on raspberries in western Washington, according to observations by Dr. E. P. Breakey. Combined with Rhothane or cryolite, however, efficiency does not seem to be impaired.

SABADILLA: Long known to possess insecticidal properties, and used for many years on livestock in Mexico, Central and South America, sabadilla is available commercially for the control of squash bugs and other insects.

The term sabadilla is generally applied to some twenty species of the genus Schoenocaulon, most of which are indigenous to Mexico. The active principal of sabadilla is confined to the seeds obtained from plants growing wild. These seeds contain a complex group of alkaloids generally referred to under the name veratrine. This term really includes a mixture of several alkaloids, the most highly toxic of which appears to be cevadine, according to investigations by T. C. Allen and others at the University of Wisconsin.

Sabadilla is available in dust form containing 10 or 20 per cent sabadilla seed with lime or pyrophyllite as a diluent. Stauffer Chemical Company offers a dust containing 0.40 per cent alkaloids with the statement that 20 pounds of sabadilla concentrate, containing 2 per cent of sabadilla alkaloids, are used in the manufacture of each 100 pounds of the dust mixture. Investigations by R. D. Eichmann in Washington State in 1944 indicate a high degree of protection against squash bugs when it is applied at frequent intervals during the season.

SELOCIDE: This is the name of a selenium compound manufactured by the McLaughlin Gormley King Company, Minneapolis. Chemically it is a solution

of selenium in potassium and ammonium sulfides. Tried out in 1939 at the Tree Fruit Experiment Station at Wenatchee, this was found very effective in the control of the Pacific mite. Where used in recent years by individual growers in the Wenatchee district in early cover sprays, fruit drop of apples occurred in a few orchards.

Because of their high toxicity to warm-blooded animals, selenium compounds are not advised for use on food crops. This accounts for the critical attitude of the Food and Drug Administration concerning selenium residues on fruits and vegetables. So far, its use in Washington has been limited. There is no residue tolerance. Fruit sprayed with Selocide is, therefore, subject to seizure if an excessive quantity of selenium is found. A definition of what may constitute an excessive amount is not clear, because selenium occurs naturally in some orchard soils, is taken up by plants, and may even be detected in the fruit.

Selenium poisoning of livestock may be chronic or acute. In South Dakota, the chronic type (alkali disease) is predominate. This results when livestock consume vegetation containing up to 25.0 p.p.m. of selenium over a period of several days or weeks. In Wyoming, the acute type (blind staggers) occurs in range areas where highly seleniferous plants are abundant. These so-called "indicator" plants may contain several thousand parts per million of selenium. Such large amounts frequently cause death within a short time when consumed by livestock, even when eaten in relatively small amounts. Although available data show much smaller quantities on fruits sprayed with selenium compounds, similar chronic effects on human beings may be assumed, following an accumulation over a period of years in orchard soils.